

# An effective tool for advanced traveller's information systems development

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## Abstract

This paper presents a tool for advanced traveller's information systems (ATIS) development and testing. The ATIS provide travellers with real time traffic information to help them make informed route choices in minimizing their travel costs. The ATIS also provide traffic managers with a powerful means to implement transport policy and to handle incidents through influencing travellers' dynamic route choice. We have developed a portable program to implement a variable message sign (VMS) based route guidance system in a simulated urban city environment. Expected travel delay is the primary information distributed by the VMS. Individual drivers' inherent characteristics (i.e. awareness and aggression), their minimum acceptable travel delay and perceived travel cost determine their dynamic route choice. The Adelaide CBD microscopic traffic model is used to test this program. The preliminary results demonstrate the capability of the program in mimicking traveller's dynamic response to VMS (and traffic information in general), which makes it an ideal tool for ATIS strategy development. This program also improves the accuracy of microscopic traffic simulation of incidents and their impact on urban traffic networks.

## 1 Introduction

The increased availability of real time traffic information and onboard navigation systems (Iguchi 2002; Miles and Walker 2006) are dramatically changing travellers' behaviour in the urban traffic environment. Individual drivers are increasingly capable of making informed route choice decisions before journey and en-route to minimize their travel cost. This trend makes urban traffic more dynamic and difficult to manage. On the other hand, it opens an opportunity for traffic managers to use real time traffic information as a means to influence traveller's dynamic route in achieving traffic network efficiency and responding to incidents effectively. The successful development and deployment of the advanced traveller's information systems (ATIS) would see an effective coordination of efforts made by both travellers and traffic managers in handling urban traffic congestion problems.

This paper presents a tool for ATIS systems development and testing in a simulated urban traffic environment. This traffic simulation approach aims to minimise costs and risks associated with the investigation in driver responses to an ATIS system, which also reduces the dependency on real ATIS infrastructure during the initial stages of the ATIS system development. The tool is built on the Transport Systems Centre's (TSC) recently completed Adelaide City Council area microscopic traffic simulation model (ACC model) which represents a typical central business district (CBD) traffic environment (Stazic et al. 2005). In this study, we choose the variable message sign (VMS) based route guidance system as a representative application of ATIS.

The microscopic traffic simulation method has been widely used to develop and evaluate advanced urban traffic signal control systems (Hansen et al. 2000; Hicks and Carter 2000; Lucas et al. 2000), freeway traffic management systems (Ozbay et al. 2006; Woolley et al. 2001a), incident detection and management systems (Dia and Cottman 2005; Zhang and Taylor 2006) and local area traffic management schemes (Woolley et al. 2001b). It contributes significantly to the evaluations of the impacts of potential intelligent transportation systems (ITS) deployment (Taylor et al. 2000). The Paramics microsimulation software (Quadstone 2000) which was used to develop the ACC model is among the most powerful software packages for micro-simulation studies. Paramics is a suite of high performance software tools used to model the movement and behavior of individual vehicles on urban and highway road networks. Three core models of Paramics (car following model, lane changing model and route choice model) form the base for simulating detailed interaction between individual vehicles and their traffic environment. Simultaneously, the characteristics of a specific driver-vehicle-unit DVU (i.e. awareness, aggression factors) influence the real time operation of each core model of Paramics, which results in different reactions from different DVUs given similar traffic conditions. In this way, Paramics reproduces daily urban traffic flow on a second by second basis.

The standard functions provided by Paramics are suitable for time-responsive traffic modelling. Vehicles are released from their origins into the traffic network following a fixed predefined time profile for a specific time period. Within the time period, traffic management of road infrastructure (e.g. lane closure or restrictions) and traffic signal control are constant. Paramics does provide dynamic traffic assignment function taking current traffic conditions into account. However, it is performed a fixed feedback period (e.g. 5 min), which only affect pre-trip route choice of vehicles to be released in the next five minutes and there is no en-route decision making after vehicle releasing. The ATIS strategies such as VMS route guidance are more event-responsive. The VMS responds to unpredictable traffic events (e.g. incidents) instead of specific time periods, which in turn requires individual vehicles respond to the VMS message dynamically when they reach the VMS sign. To model such an ATIS application, the Application Programming Interface (API) of Paramics is utilised in this study and specific code is developed to extend and override (if needed) the default standard functions of Paramics. The resultant application program is portable, which works with the ACC model as a 'plug-in' to implement the ATIS functionality.

This paper is organized into five sections. In Section 2, we identify the research problems associated with VMS route guidance application and present our approach to handle these problems. Then the VMS route guidance program and its interaction with Paramics are detailed in Section 3. Section 4 discusses the preliminary results of running the program with ACC model. Finally, conclusions are made and future research directions are recommended in Section 5.

## 2 Methodology

The nature of VMS route guidance involves traffic information gathering, traveller information distribution, and most importantly, individual traveller's route choice decisions (to stay on the original route or select an alternative route). In the microscopic traffic simulation context, we use the term DVU to represent the moving object (i.e. the vehicle and its driver) in the traffic network. The primary stimulus for a DVU to change its normal route is expected travel delay. The final route choice decision relies on the inherent characteristics of each individual DVU. The way in which traveller information is distributed also influences the effectiveness of the VMS route guidance application. How the information distribution is simulated also influences the reliability of our VMS program in mimicking a real world VMS application.

### 2.1 Travel time estimation

Travel time represents spatial traffic information related to a specific link (or set of consecutive links) of the traffic network. In our program, we use real time expected travel delay to influence individual DVU's route choice. Reliable and representative travel time information in the CBD environment is very difficult to obtain using probe vehicles, and to estimate this value from other traffic measurements (e.g. volume, speed, and occupancy) remains a challenge. In this study, we propose a sampling method to obtain average travel time of a specific link.

Taking advantage of the Paramics API, we can obtain travel speed  $v_i$  of each individual DVU at each simulation time step (e.g. 0.5s) on our targeted link. If we set the travel time estimation interval to 2 min, then we can have 240 sets of speed samples with each of these sets containing speed samples of all vehicles on the link at a specific time step. Hence, the average travel speed  $v_a$  of the link for the last two minutes would be:

$$v_a = \frac{1}{n} \sum_{i=1}^n v_i \quad (1)$$

where  $n$  is the total number of samples collected from the link during entire two minutes periods, which represents all moving vehicles.

Note that we are dealing with a CBD environment and intersection travel delay (both geometric delay and stop-line delay) imposed on each individual vehicle needs to be taken into account. We can deliberately separate moving vehicles from stationary ones when we provide a cut off threshold for travelling speed (i.e. 1.0 m/s). This threshold was chosen to replicate GPS systems that also use this value to identify stationary objects. This proposed sampling method has the potential to mimic future

travel time estimation when GPS units are commonly used by travellers. We now have two groups of speed samples: one group contains  $n$  speed samples for moving vehicles (see  $n$  in equation (1)), and the other group has  $m$  samples for stationary vehicles during the same travel time estimation period.

We introduce a parameter  $r\_move$ . This parameter represents the proportion of link travel time used for actual travel. In fact, vehicles only use this proportion of time to complete their journey on the specific link instead of total link travel time.

$$r\_move = \frac{n}{m+n} \quad (2)$$

The length of the targeted link ( $l$ ) is known as is the value of the  $r\_move$  variable for the last two minutes. Now we can estimate the average link travel time  $t_a$  using the following equation:

$$t_a = \frac{l/v_a}{r\_move} \quad (3)$$

## 2.2 Information distribution

In the traffic simulation environment, traveller information distribution via VMS is quite different from the real world VMS application. In reality, travellers firstly need to identify the VMS, then it is up to individual traveller to decide whether they are going to read the VMS message or not and finally whether to change their travel behaviour. In the simulation, we have to answer the following three questions in order to make our VMS route guidance have an effect:

### 1. Where to distribute the information?

It is quite clear that traveller information should be delivered to DVUs on the link where the VMS is located (on the VMS link). In Paramics, the VMS itself is only a display tool instead of a control device. We have to make sure that only when DVUs have reached the VMS link, the information becomes available to them. We do not want the real time traffic information be used for pre-trip planning but for en-route guidance, which is distinguished from dynamic traffic assignment provided by Paramics. It should be noted that this location based displaying of a VMS in Paramics can also be used to inform drivers on a route that their first-choice car park became full so that they can re-route to other available car park.

### 2. When to distribute the information?

As we know, the primary stimulus for a DVU to change its normal route is increased individual delay. This implies that if the estimated link travel time is close to the normal free flow travel time, it does not make sense to distribute such information to DVUs, and we do not want them to make route changes as well. In addition, the repeated decision making performed by DVUs in this scenario imposes a heavy computational load on the software as such calculations have to be performed at each simulation time step (e.g. 0.5s). In our VMS route guidance program, we start to distribute travel time information when the estimated travel delay on the targeted link exceeds a certain threshold (e.g. 5 min).

### 3. Who should read the VMS message?

This question deals with the selection of candidate DVUs to obey VMS route guidance. Not every DVU that reaches the VMS link is going to use the targeted link where the travel delay is estimated. The potential users of the targeted link need to be determined as the candidate DVUs. We focus on the destination zone of each DVU on the VMS link. After analysing the traffic network, we are able to construct a list of destination zones so that the targeted link is more attractive to DVUs whose destination zone is mentioned in the list. These DVUs become our VMS control targets.

### 2.3 Driver's route choice decision

Individual DVU dynamic route choice forms the core of our VMS route guidance program. Individual driver's characteristics greatly influence their car-following and lane-changing behaviours, which are represented in Paramics using awareness and aggression variables (Quadstone 2006). In our program, these characteristics play a key role in route choice decision making. We still allow both awareness and aggression of DVUs to follow a normal distribution even though Paramics allows users to customise the distribution of these factors.

We know that aware drivers tend to have plenty of time to judge traffic conditions (e.g. they will change lanes much earlier in order to make a turning manoeuvre) and obtain information from VMS to make more informed route choices. If the awareness of drivers is low, they may not have time to read VMS messages and the likelihood for them to follow VMS guidance is low. Aggressive drivers keep seeking opportunities to reduce their travel cost by frequent lane changing and selection of faster routes. Conservative drivers tend to adhere to their usual lane or familiar route as much as possible. To incorporate these differences into our DVU route choice decision process, we create a score board for each candidate DVU. If a DVU's aggression (range from 1 to 9) exceeds our predefined threshold, then the chance for this DVU to accept VMS guidance will increase by +1 point. Otherwise, the chance will be reduced by one point. The same process applies to the DVU's awareness variable (range from 1 to 9).

As mentioned before, the primary stimulus for a driver to change route is expected increase in delay. The route choice decision is the result of balancing between the individual DVU's patience and its expected travel delay. To describe the balancing action, we define two linear distributions of individual DVU patience over its awareness and aggression respectively. They share the same centre point  $p_a$ , the average acceptable travel delay for certain user group (e.g. familiar or unfamiliar) to which the DVU belongs. The linear combination of these two distributions gives us the patience  $p_i$  for the DVU  $i$

$$p_i = p_a * (0.5 * \frac{10 - agg_i}{5} + 0.5 * \frac{10 - awa_i}{5}) \quad (4)$$

where  $agg_i$  and  $awa_i$  represent the aggression and awareness of the DVU  $i$  respectively. If the estimated travel delay exceeds the patience of the DVU, then the chance for the DVU to accept VMS guidance increases by +1 point. Otherwise, the chance will be reduced by one point.

In addition, two other factors, trust in the VMS and individual DVU's perceived travel cost, are also used for route choice decisions. The linear combination of the awareness and aggression of each candidate DVU forms its trust level of the VMS message. The DVU's perceived travel cost on the targeted link is decided using both the perturbation rate of the DVU and a random number generated at the time when the DVU reaches the VMS link. If trust level is greater than our predetermined middle point or the estimated travel cost exceeds the DVU's perceived cost, the extra one point will be added to its score board. Otherwise, one point will be deducted from the score board. After taking into account the above five factors, if the final score of the candidate DVU is positive, then it will follow the VMS route guidance.

### 3 VMS route guidance program

The VMS route guidance program is developed using C language. The Paramics API allows our program to augment the core Paramics simulation with new functions, driver behaviours and practical features. Four types of API function calls have been made in the program, which include:

- Override standard code **QPO** – override the standard default behaviour inside Paramics;
- Extend standard code **QPX** – add new functionalities to Paramics, which can be triggered by one of a large number of events. This type of function call let us add new code / functions to the Paramics simulation. The following text provides an example of such function calls indicating where the user defined function is placed in the Paramics simulation loop:
  - **void qpx\_CFG\_parameterFile(char \*filename, int count)** - called when an API parameters file is specified by the user;

- **void qpx\_NET\_timeStep(void)** - called at the start of each time step during the simulation run.
- Obtain a value from the standard code **QPG** - retrieve data from within either the simulation or graphic engines inside Paramics;
- Set a value in the standard code **QPS** - set a data value, or change / add to the view displayed.

Through these function calls, travel time estimation, information distribution and individual DVU route choice decisions can be performed within Paramics at each simulation time step.

The VMS guidance program is implemented via Dynamic Linked Libraries (DLL files). Each time when the Paramics Modeller starts to load the ACC model, it automatically searches for user developed DLL files, such as the VMS route guidance program, and loads them on request. The Paramics Modeller treats the user defined program as its 'plug-in' function.

### 3.1 Running VMS route guidance program in Paramics

The conceptual diagram (Figure 1) shows how the Paramics Modeller interacts with VMS route guidance program to implement ATIS strategies. The Paramics API provides access for the user developed VMS route guidance program to control and modify the core modules of Paramics. Two steps are required to run the ACC model with VMS route guidance functions: 1) load the ACC model with VMS route guidance program and 2) perform VMS route guidance.

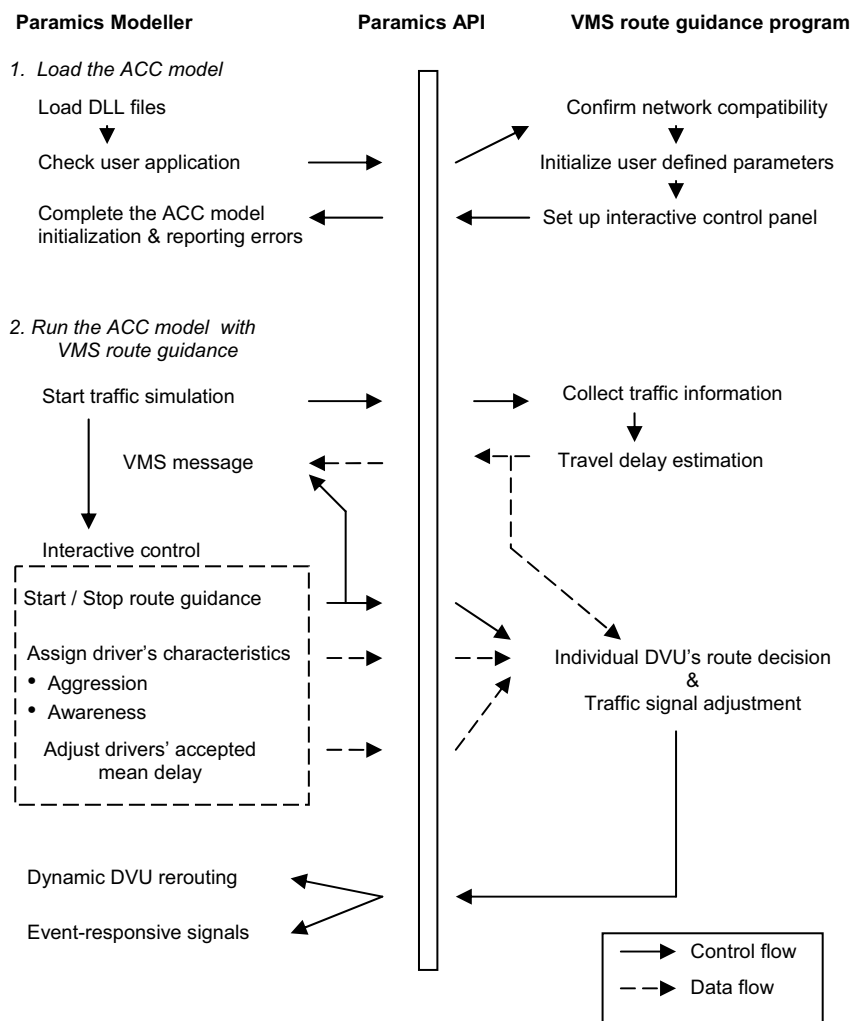


Figure 1 Interaction between Paramics and VMS route guidance program

#### *Step one - load the ACC model*

To load the ACC model, the Paramics Modeller checks the ACC model's 'configuration' and 'programming' files first to determine which user developed program files (DLL files) and their associated parameter files should be loaded. Then, the Modeller checks the compatibility of the ACC model's key elements to which the user program will gain access. This procedure can reduce the risk of model crashes during simulation. The information about the model's compatibility is displayed in the Modeller's report window.

Once passing the above procedures, the user program starts to initialize all the user defined parameters used for VMS route guidance and to set up a control panel (a pop-up display window within the Paramics GUI) for interactive simulation.

#### *Step two - implement VMS route guidance*

During traffic simulation, the interaction between the Paramics Modeller and the VMS route guidance program takes place at each simulation time step (i.e. 0.5 s). The Modeller keeps monitoring the control panel and responds to each function call initiated by the user program to perform the VMS route guidance. The function calls include collecting traffic data from the targeted link, updating VMS messages and assigning new routes to individual DVUs. The effects of these function calls would see the changes of VMS message in response to current traffic conditions, event-responsive traffic signal control, and individual DVU reaction to the changing traffic conditions.

### **3.2 Individual DVU's route choice**

The central element of the entire VMS route guidance program is the individual DVU's route decision (see Figure 1). This element fulfils two major functions of VMS route guidance: information distribution and individual DVU route choice. During traffic simulation, this part of the program keeps checking whether the following four conditions are met at each simulation time step in a serial manner (the checking will continue only if the previous condition is met):

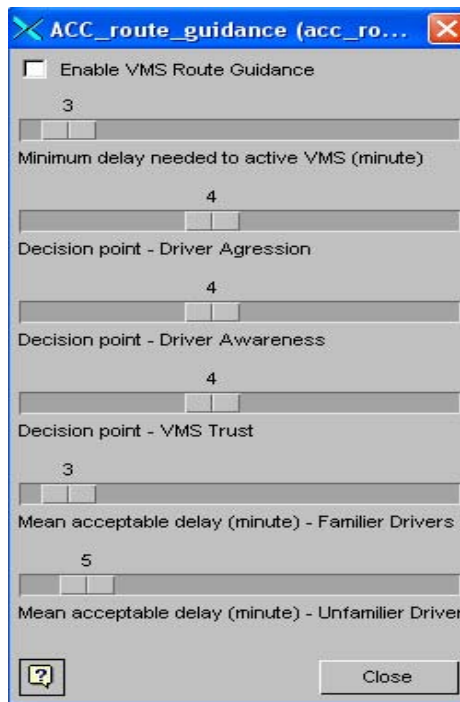
1. Is the VMS control activated? VMS is activated when both a) the VMS route guidance is enabled, and b) the expected travel delay exceeds a predefined threshold.
2. Is a DVU currently on the decision making link where the VMS sign is located?
3. Whether this DVU is currently not under VMS guidance?
4. Does the DVU's destination belong to the targeted destination zone list?

If a DVU passes the final three checks, it then becomes the candidate DVU that has the potential to accept the VMS route guidance. This assessment procedure forms the first part of the *Individual DVU's route decision*.

For a candidate DVU to make a final route choice decision, a voting system is set up. Both the characteristics of the DVU and its surrounding traffic environment contribute to the route choice. This voting system has been discussed in detail in the Methodology section and forms the second part of the *Individual DVU's route decision*.

### **3.3 Planning with certainty**

During the traffic simulation, we can adjust certain parameters through the control panel (see Figure 2) to influence the DVUs' behaviour. This feature of the VMS route guidance program provides the user with the additional capability to monitor and control the progress of each traffic simulation run, essential for any ATIS strategy development and testing.



**Figure 2 Control panel for VMS route guidance**

Some research in Australia has suggested VMS compliance rates around 15 to 35 per cent (Ramsay and Luk 1997). In contrast to setting a VMS compliance rate in advance and randomly picking up vehicles to obey the VMS route guidance, we use individual DVU's characteristics and its surrounding traffic conditions to decide whether the DVU should follow the VMS route guidance or not. The amount of traffic diversion can then be matched with data collected by the stated preference (SP) and revealed preference (RP) surveys (Furosawa 2004) by adjusting the VMS parameters. In this way, we can improve the simulation of driver's route choice in response to VMS (and to traffic conditions in general) using empirical findings and our travel experiences. Meanwhile, we can explain the traffic simulation results with increased confidence.

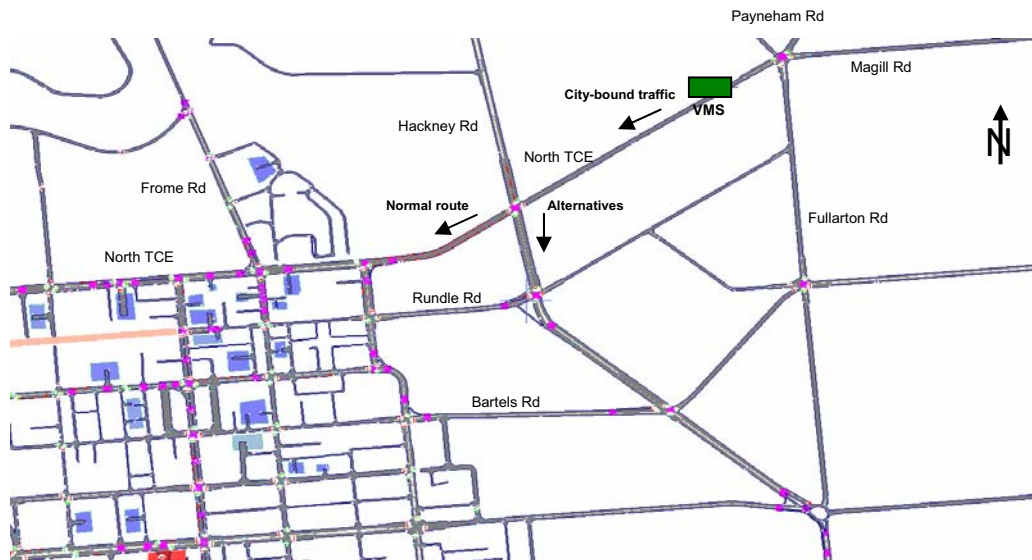
#### 4 Preliminary results

The two objectives of developing the VMS route guidance program include:

1. enhanced capability of simulating individual DVU dynamic response to VMS messages (specifically, travel time information),
2. the program is portable and it can work with large scale CBD traffic models to assist ATIS strategy development and evaluation.

The Adelaide CBD traffic network has been modelled in three stages to eventually become the one combined model: 1) the CBD South, 2) the CBD North, and 3) the CBD Ring Road. This modelling project was supported by a 3-year ARC linkage grant. The ACC model has been developed using the standard functions provided by Paramics. The CBD South network constitutes the most feature intensive of the three networks. It is a grid type road network with a huge number of alternative routes. The CBD Ring Road is an important part of the project, which allows route guidance and the potential effect of traveller information systems to be investigated, as well as possible traffic impacts on the surrounding metropolitan area. Therefore, the ACC model provided an appropriate platform for testing our VMS route guidance program.

The test site of the VMS route guidance program is located in the north-eastern corner of the CBD South, which includes part of the Ring Road system (Hackney Road). Figure 3 shows the network geometry for the test site.



**Figure 3 Test site for VMS-route guidance program**

The VMS route guidance program uses the link travel time of one section of the North Terrace (between King William Road and Hackney Road, the targeted link) to influence the route choice of city-bound traffic heading to North Tce from Magill Road, Payneham Road and Fullarton Road. The VMS panel is located next to the intersection between Magill Road and Payneham Road further downstream (see Figure 3). 'Drive Safely' is the normal display of the VMS panel. Once the travel delay on our targeted link exceeds a predefined threshold, the VMS panel starts to display the estimated travel delay the travellers might encounter. The program distributes this information to travellers who are currently on the VMS link and are going to use the targeted link (North Tce).

In addition to influencing traveller route choice, the VMS route guidance program has the capability to adjust traffic signals of the intersections along the alternative route (if needed) to facilitate significant traffic diversion. This capability can be used in the future to develop ATIS based traffic management strategies in order to reduce the congestion level of North Tce during morning peak periods.

#### **4.1 General findings**

The ACC model was run with the VMS route guidance program during morning peak periods. The general finding was that DVUs respond to the VMS differently just like real world traffic, dependent upon individual DVU destination, awareness, aggression, and patience. In particular:

1. DVUs who are going to use North Tce and encounter increased travel delay tend to respond to the VMS message,
2. Though the majority of incoming DVUs to North Tce still follow their normal route, the number of DVUs who do respond to the VMS message is positively correlated to the estimated travel delay, which is as shown in Table 1.

**Table 1 Number of vehicle rerouting vs expected travel delay**

Estimated travel delay (min)	5	5	6	13	14	16	19	20	31
Number of vehicles rerouting (at each 2 min interval)	0	0	2	6	8	11	18	16	13

This table is obtained when the parameters are set as follows: minimum delay required to activate VMS route guidance system is 5 min; mean acceptable delay for familiar vehicles is 10 min; and mean acceptable delay for unfamiliar vehicles is 15 min. These settings are based on general traveller's behaviour in Adelaide (Furosawa 2004). The last column of Table 1 represents the already congested situation where significant reduction of traffic volume is observed on the VMS link. Therefore, the total number of candidate vehicles who are going to make route choice decisions decreases as well.

The above figures indicate that a very small traffic diversion occurs when the expected travel delay is less than 10 min. When the expected travel delay is greater than 15 min, the number of vehicles that follow the VMS route guidance increases. The VMS compliance rate for a typical 18 min period of VMS operation is around 22 per cent. These results coincide with the former studies on driver's route choice (Furosawa 2004; Ramsay and Luk 1997) and with our own driving experiences in the Adelaide City. It demonstrates the capability of the VMS route guidance program in mimicking real world VMS application, and makes the program an ideal tool for future ATIS system development.

## **4.2 Simulation of incidents**

Another important finding is that the VMS route guidance program may also indirectly assist with more accurate traffic modelling in the case of incidents. As an example, if we create a capacity reduction incident on North Tce during the morning peak period, and we disable the VMS route guidance functions, two distinct traffic scenarios are observed during simulation:

*Scenario I:* All-Or-Nothing traffic assignment is selected

After a short period of incident duration (around 10 minutes), we observe the full blockage of North Tce. The explanation could be that without updating travel cost information and passing it to travellers, all city-bound traffic heading to North Tce adhere to their normal route all of the time.

*Scenario II:* Dynamic traffic assignment is chosen with 5 min feedback period

Although there is no complete blockage occurring on North Tce, we notice a periodic traffic oscillation on the link. The underlining fact is that the periodic feedback of travel cost on North Tce is used by Paramics for pre-trip route planning. Therefore, all the vehicles to be released during the next 5 min tend to shun the North Tce route completely.

Although a function of calibration of the model, none of these scenarios represents the true effects of incident impact in the real world. The parameters that can be controlled by the VMS add on (shown in Figure 2) allow for more realistic modelling of DVU behaviour in response to an incident without the need for the VMS guidance functionality to be fully activated. There are therefore benefits in using the VMS program even when VMS route guidance is not required.

## **5 Conclusion**

This paper presents a tool for ATIS development and testing in a simulated urban traffic environment. Through developing the actual VMS route guidance program and testing it using the Adelaide City Council area microscopic traffic simulation model, the capability and potential of this tool has been demonstrated:

- It works seamlessly with large scale complex (multiple alternative routes) micro-simulation traffic models;
- It provides enhanced capability to simulate individual traveller dynamic route choice in response to both normal and incident conditions;
- It provides interactive control of vehicle route choice behaviour during traffic simulation.

This tool extends the capability of normal micro-simulation traffic models and facilitates broader ITS strategy development and evaluation.

Immediate future research will be using the VMS route guidance program to develop traveller information based traffic management strategies for the ACC network and to investigate the impact of new strategy implementations. More work is also required in quantifying individual DVU response to VMS in the Australian context. Future research will also investigate the expansion of the VMS model to incorporate the distribution of traveller information to other formats such as onboard systems and vehicle specific systems.

The VMS route guidance plug-in could potentially be used to simulate and determine the amount of necessary vehicle diversion away from specific road in order to achieve certain traffic performance on it and then try to apply appropriate strategies to achieve that traffic diversion in the real life.

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