Introduction

Traffic incidents, such as an accident or a broken down vehicle, are causing more than half of all congestion delay and are often responsible for a number of secondary accidents. In an attempt to minimise the effects of incidents, various Incident Management (IM) plans have been developed and implemented in many countries. The majority of these plans concentrate on early detection and clearance of the incident, and aim to coordinate the actions of the various institutions involved. However, traffic management during the incident is usually the weakest link in the chain of IM plans. This is due to the fact that effects of an incident are difficult to predict. Empirical data on the effects of incidents are very difficult and expensive to obtain from field surveys, and it is even more difficult to establish general trends from the data collected for a few specific incident location, time, duration and severity. Also, field surveys do not allow professionals to evaluate the effects of their proposed control strategies.

Through simulation modelling, incidents with varying severity, time of occurrence, duration and location may be investigated and the effects of various proposed control strategies may also be evaluated. SITRAS is a microscopic traffic simulation model developed at UNSW to simulate urban road networks including incidents of varying types (Hidas and Behbahanizadeh, 1998). The simulation outputs provide a wealth of performance indicators (PIs) that can be used to evaluate various traffic management alternatives. The model is currently being further developed for the NSW Roads and Traffic Authority (RTA), and is intended to be used in the preparation and investigation of Incident Management Plans by the RTA Traffic Management Centre (TMC) staff.

One of the most promising traffic management measures during traffic incidents is the use of traveler information systems to inform drivers in real time about the traffic conditions, the presence of incidents, and the expected delay. Real time traffic information can be disseminated through several media such as radio channels and/or Variable Message Signs (VMS) installed beside or above the carriageway. These systems may help drivers to avoid the congested area by diverting to less congested links in the network. Several studies from various countries have also shown that the proportion of drivers diverting is highly dependent on a number of factors including the message content displayed on the VMS, that is the *cause* and the *severity* of the incident. If the diversion rate for various message contents can be predicted to a reasonable accuracy, this can be used as a valuable traffic management tool during incidents: a simulation model can estimate the 'optimum' diversion rate for any incident scenario, then the appropriate message content can be selected which would be most likely to generate the required diversion response from motorists.

Early field studies at VMS locations have found evidence of traffic diversion in the range of 5 to 80 % of the total driver population subjected to the message. This range is clearly too wide for prediction and modelling purposes. In the last decade several international research studies have been conducted to investigate the influence of various VMS messages on drivers' route choice behaviour and to establish quantitative models of diversion rates. While these studies provide a better understanding of the factors influencing route choice behaviour in response to real time traffic information, the proposed models have serious limitations in predicting diversion rates under different conditions and in other countries. There is a need to develop more general models for prediction purposes in Australia and to calibrate such models based on local data. No information of this kind is available in Australia.

The aim of this part of the incident modelling project, reported in this paper, is to review the literature on the effects of Variable Message Signs (VMS) on drivers' route choice behaviour under incident conditions and to investigate how these effects can best be modelled in SITRAS.

The paper is organised as follows. The next section describes the material found in the more recent literature on VMSs and their effects on traffic. It discusses attempts made at modelling VMSs by other researchers. Section 3 utilises what is found in the literature to formulate an approach to modelling VMSs in SITRAS. Details of routines and parameters to be included in the model are described. The last section summarises the conclusions of this part of the project and recommendations for further work.

Literature Review

Roadside Variable Message Signs have been installed in many countries for many years as a means of communicating with drivers. These displays can be used for various purposes including safety warnings, capacity variation, parking guidance and information, and flow diversion. This review is focused on the use of VMSs for flow diversion purpose only.

There is now a large body of literature dealing with route choice in response to VMS. This paper is not intended to provide a comprehensive overview of the topic. Rather, its purpose is to review those recent publications which can provide a useful basis for developing an approach to modelling VMSs in the framework of simulating incidents and developing Incident Management Plans.

Bonsall and Merrall (1996) collected data on drivers' route-choice responses to roadside VMS messages, using the VLADIMIR route choice simulator. The work was based on two networks; one urban (the town of Aalborg in Denmark) and one interurban (in central Scotland). The VMS messages included information on one or more of the following items:

- location of an incident on the network
- nature of the incident (eg. roadworks, accident, queues)
- warning of delay (at location specified or implied)
- estimate of delay (at location specified or implied)
- recommended route to specified or implied destination.

Each subject was asked to 'drive' (in fact, simulated by using VLADIMIR sitting in front of a computer) to a given destination once without any VMS messages being shown, and again (a year later) with VMS messages being shown at the appropriate places but with network conditions being otherwise identical. A total of 457 persons were interviewed, providing more than 20,000 data points on route choice behaviour. Some of the relevant findings from the study are:

- inherent ambiguities in the VMS message may lead to quite a different or even opposite effect to that which had been intended;
- more expensive message formats (eg. coloured pictograms) were not noticeably more effective than their cheaper counterparts;
- the effectiveness of an individual message (measured in terms of its ability to persuade drivers to divert from their previously favoured route) is a function of
- site factors: the extra travel time needed on the diversion route in normal traffic conditions, and the existence of other potential diversion points further downstream
- message content:
  - whether a delay is mentioned and if so how much?
  - whether the cause of the incident is mentioned and if so what is it?
  - whether a diversion is recommended and if so whether it is allied to specific destination(s)
- driver characteristics, most importantly familiarity with the network.

Some more specific findings are:

- a message mentioning roadworks will have less impact than one mentioning an accident (other things being equal)
- the more detail is given (on cause, seriousness, routes) the more persuasive the message will be
- the greater the quoted delay the more effective the message will be
- some messages have more effect on drivers who are familiar with the network while others have most effect on unfamiliar drivers.

The authors have also proposed and calibrated a number of discrete choice logit models which could be used to predict route choice decisions at a particular point in the network under the influence of a VMS message. They used a number of network-, VMS- and driver-specific attributes and explanatory variables in these models in an attempt to quantify the importance of these effects on route choice. The statistical analysis of the data has shown that people with different levels of network knowledge have significantly different responses to the same VMS message.

Wardman *et al.* (1997) used a Stated Preference (SP) technique to explore further details of drivers' response to a wider range of VMS messages. The survey was based on a 34 km interurban trip outside Manchester City. The choice context included 4 distinctly different routes leading to Manchester City, two of which were up to motorway standards, one dual carriageway and one single carriageway highway. Respondents were asked to assume that they were travelling to the city centre on one of the motorways and that, as they approach a major interchange, they see a VMS panel displaying information about traffic conditions ahead. They were presented with a pictorial representation of the choice context, showing 'through-the-windscreen' view of the traffic conditions ahead and on the off-ramp, and the VMS panel displaying a text message. The text messages included a combination of information on the magnitude of delay (in a range from 'all clear' to 30 min) and cause (accident, congestion or roadworks). Respondents were asked to make a choice in the light of the picture and a reinforcing written description. A total of 289 completed questionnaires were collected providing 2304 choice observations.

The collected data were used to calibrate a number of multinomial logit (MNL) models in order to quantify various factors affecting the respondents' route choice behaviour. The results were also used to forecast the likely effects of various VMS messages on the proportion of drivers staying on the main motorway. Some of the relevant findings are summarised below.

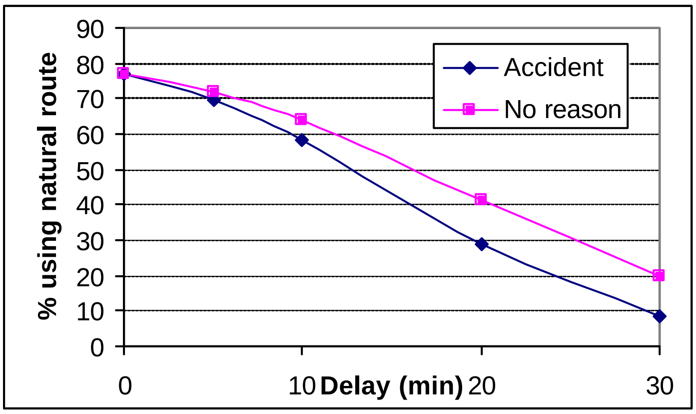

Figure 1 The effect of delay time on proportion using the natural route

Figure 1 illustrates the effects of VMS messages quoting various levels of delay time in minutes for the cause which has the larges impact on choice (Accidents) and the cause which has the least impact (No cause). The effects of a message indicating congestion and roadworks as cause were between the effects of these two causes shown on Figure 1.

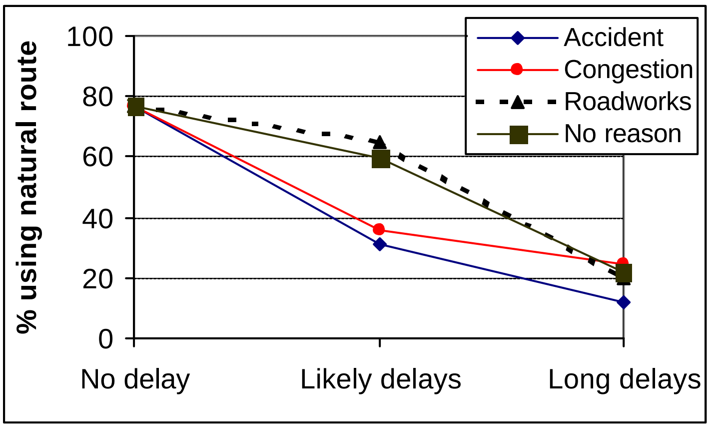

Figure 2 The effects of qualitative factors on proportion using natural route

Figure 2 presents forecasts of the effects of qualitative indicators of delay associated with various causes indicated in the VMS message. Again it can be seen that Accident cause produces the largest impact on choice, while Roadworks and No reason create lower impacts, but the differences are only significant when the likelihood of the delays is unclear.

While the numerical results are site-specific and therefore not simply transferable, the study provides useful insights into the general nature of relationships likely to prevail at other VMS sites. The finding that different stated causes of delay have different impacts is particularly important. The study also showed that visible queues have a significant effect on route choice, particularly for drivers more familiar with network conditions. It is also interesting to note that a blank VMS screen is interpreted differently from a positive ALL CLEAR message.

Bonsall and Palmer (1998) conducted further analyses of data previously collected using the VLADIMIR route choice simulator, to explore further details related to the influence of the content and phrasing of the VMS message. Discussing the effectiveness of VMS messages they provide a useful categorisation of the message content:

- a description of the *cause* of an incident or obstruction
- a description or quantification of its *effect*
- an indication of its *location*
- sometimes *route instruction* or *route advice*, directed to all or a subset of drivers.

They then provide a review of the evidence on the effectiveness of different messages, based on data collected in Denmark, Scotland and Leeds. Findings can be summarised as follows:

- Messages which include a description, preferably quantified, of the effect of the problem are more effective (ie. induce higher diversion rate) than signs simply giving directional advice.
- Quantified estimates of delay are easier for drivers to interpret than lengths of queues.
- Unquantified estimates of delay (eg. delays likely, long delays) produce widely varying responses at different VMS sites.
- Combinations of cause, effect and route advice are particularly influential, but the mention of roadworks reduces the diversion rate.
- Messages describing minor problems may be counter productive if the quoted level of delay is perceived as less serious than the expected normal condition.
- The effectiveness of a particular message depends on the proportion of the passing drivers for whom it is relevant, the relative attractiveness of the potential diversion route, the local traffic conditions and the characteristics of the drivers.
- The most important driver characteristic is the level of familiarity with the network.
- The credibility of the VMS system also has an influence on the level of compliance.

The paper provides some numerical estimates on the effects of the relative attractiveness of the potential diversion route. This relative attractiveness can be measured by the extra time to comply (ETC), which is defined as the minimum extra travel time that a driver would experience *under normal traffic conditions* if he/she used the diversion. Figure 3 shows the compliance rates as a function of ETC for an interurban journey of 75 minutes normal travel time, based on Scottish data. Figure 4 shows similar results for an urban trip of 15 minutes normal travel time, based on data collected in Leeds. While the numerical values are not directly transferable, the relationships can be used as a general basis for modelling purposes.

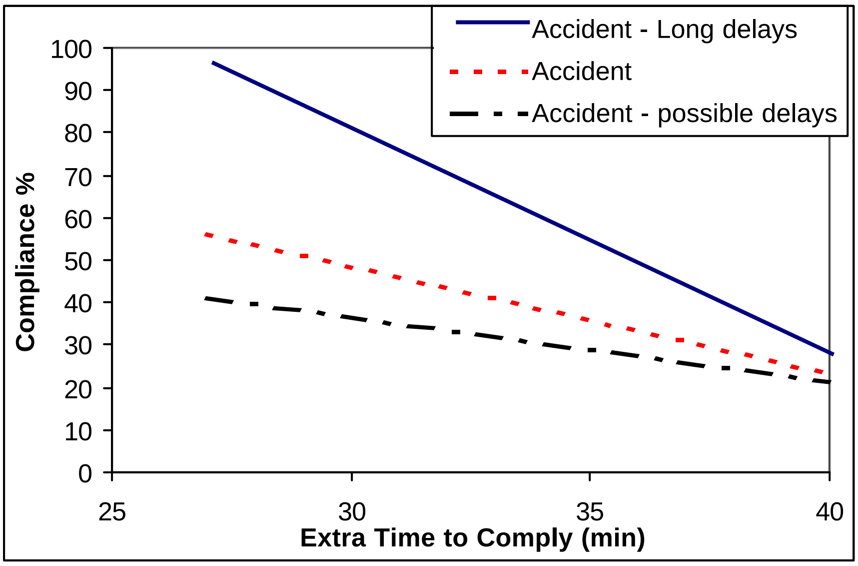

Figure 3 Compliance as a function of extra travel time (journey time: 75 min)

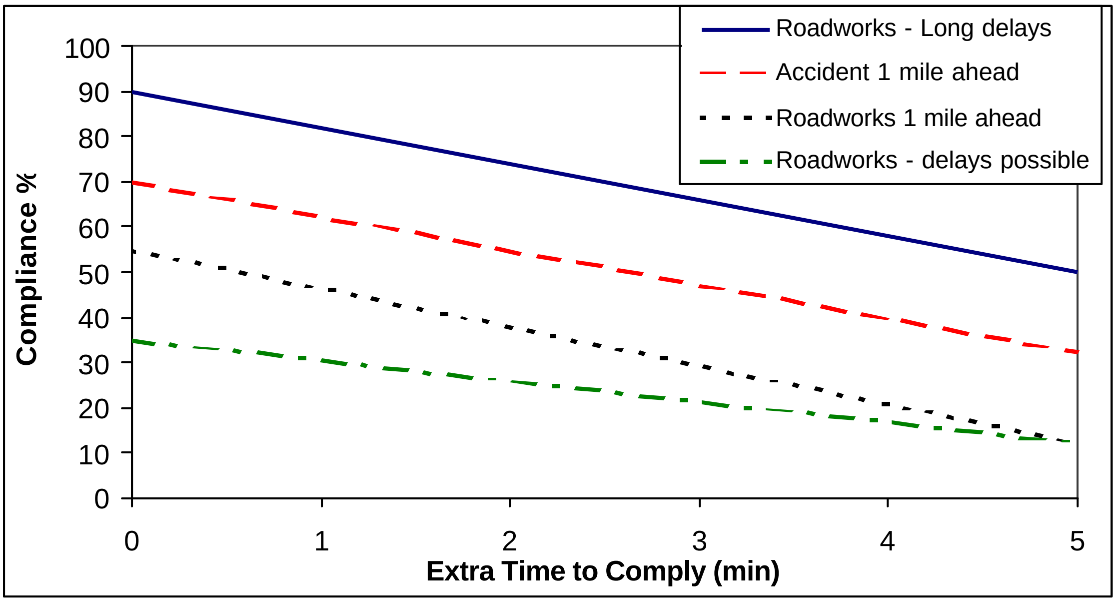

Figure 4 Compliance as a function of extra travel time (journey time: 15 min)

It is important to note that ETC may be the most important, but clearly not the only factor affecting the effectiveness of the VMS message. Visible network conditions, such as the presence of queues on the normal and/or the alternative routes and whether the alternative route is aligned as a natural continuation of the route which the driver is already on, also have a significant influence on compliance levels.

From a network management viewpoint the most important conclusion of the paper is that, given that the level of compliance appears to depend on the VMS message content, it should be possible, within limits, to select messages which achieve a desired level of diversion.

Chatterje and Hounsell (1998) describe a modelling approach for the evaluation of network impacts of driver response to VMS, using RGCONTRAM, a development of the CONTRAM dynamic traffic assignment model, specifically designed to model traffic information systems. In RGCONTRAM vehicles set off with pre-defined routes, but instead of being assigned through to their destination, are moved a link at a time in appropriate sequence according to their travel time, and can change route according to diversion rules. At the VMS site route choice is reconsidered using a probability model of the form

$$\log(p/(1-p)) = k + m\ MES + e\ ETC + a_1 X_1 + a_2 X_2 + \ldots$$

where

p	proportion diverting,
MES	message content,
ETC	extra travel time to comply in non-incident conditions
X_i	driver/journey characteristics
k, m, e, a_i	parameters estimated by the model.

When calculating the probability of diversion, one difficulty is identifying an appropriate alternative route which avoids the influence of the reported incident. The authors propose the use of travel time multipliers applied to links between the VMS site and the incident site. These links are thus perceived by drivers passing the VMS to take longer than in normal conditions. The link multipliers depend on the distance of the link from the incident, the relevance of the link (ie. amount of traffic using link that also normally passes the incident link) and incident severity.

A stated preference survey was conducted in London to obtain data specific to the network conditions. Two thousand self-completion questionnaires were distributed to drivers. The results are currently being analysed to calibrate the model parameters. In the meantime some initial model runs were made using simple assumptions about driver response. The modelling process used for incident evaluation requires several model runs:

- first CONTRAM is run to generate routes used in normal conditions,
- then RGCONTRAM is run to model the effects of the incident without VMS,
- finally RGCONTRAM is run again with VMS.

In the last run drivers passing the VMS sign are diverted to fixed diversion routes using the probability function described above. Evaluation is based on a comparison of the driver/network performance in the three model runs. Results from the initial case study – the effects of a one hour incident blocking one lane on a major motorway - demonstrate the network consequences of several possible scenarios:

- if drivers stay on their normal routes, the drivers on the incident links experience large delays, but other drivers are hardly affected
- in the unlikely scenario when drivers have perfect knowledge of network conditions, no category of drivers experiences significant delay
- as different diversion proportions lead to different overall network conditions, modelling various scenarios can help to identify the range of diversion proportion which produces a close-to-optimum conditions.

Implementation concept of VMS modelling in SITRAS

It can be concluded from the literature review that, when faced with a VMS message, the decision of a driver whether or not to divert is influenced by the following factors:

1) VMS message content, which has several components:
   - *cause:* accident, congestion, or roadworks
   - *severity:* length and/or probability of delays

2) the relative attractiveness of the alternative routes, measured primarily by the Extra Time to Comply (ETC), but secondary factors, such as visible queues, network topology, may also be considered,

3) driver characteristics, most importantly familiarity with the network.

Information relevant to factors (2) and (3) are available in SITRAS. A new Link Control object is defined to represent a VMS panel and to perform the actions related to its message.

The VMScontrol object

VMScontrol is derived from the LinkControl object, which implements the basic functionality for all descendants. This enables a VMScontrol to be attached to any link in the network, and it will be updated at every simulation interval (one second). What actually happens in this update process is to be defined in every descendant object.

Parameters of the VMScontrol object include:

- Link: a reference to the Link which it is attached to
- Position: the distance from the end of the Link where the VMS panel is located
- Visibility: the distance within which drivers on the Link may see the message

- Message: a text representation of the displayed message, used only for display purposes
- Cause: a category indicating the cause component of the Message. Categories will include: NoCause, Accident, Congestion, RoadWorks.
- Severity: a category indicating the severity component of the Message. Categories will include: Unknown, Low, Medium, High.
- Affected Links: this is an ordered list containing references to links which are affected by the Message: first is the link immediately after the VMS site, last is the link of the incident site reported in the Message.

The VMScontrol object has a number of routines dealing with setting, changing and displaying a Message. From an operational viewpoint the most important routine of the object is the **Update routine** which is executed at every interval during the simulation. This routine does the following:

- first it checks if there is a meaningful Message currently displayed; if not, there is nothing else to do.
- if there is a Message that may affect drivers route choice, then it searches the link object which the VMScontrol object is attached to for vehicles upstream of Position up to Visibility, and it passes on relevant parameters of the Message to each vehicle found. Relevant parameters include: Cause, Severity and Affected Links.
- the routine also checks whether there is any user-set change in the current Message content, and if so, it calls other routines to carry out the required changes.

Driver response to a VMS Message

Vehicles in the visible range of a VMS site receive the Message from the VMScontrol object through a call to the ProcessVMSmessage routine of the vehicle object. This appears to be the most effective way of handling the message as only those vehicles are affected which are able to see the message.

Based on the information contained in the VMS message, and also taking into account its own driver and trip characteristics, the vehicle has to decide whether to divert to an alternative route or to continue its route previously selected assuming normal traffic conditions. In order to explain the suggested process involved in this decision-making, we need to briefly describe some details of the normal route selection process implemented in SITRAS.

The normal route selection process: SITRAS allows modelling two basic categories of vehicles/drivers: *unguided* vehicle drivers represent the 'normal' category, while *guided* drivers/vehicles may be used to represent vehicles fitted with in-vehicle guidance systems which provide up-to-the-minute advice to the driver on the 'best' (practically shortest travel time) route to the intended destination. Separate route selection processes are implemented for the two categories in SITRAS. In this Incident Modelling Project we intend to deal with the unguided category only. Note that the vehicle objects in SITRAS represent a combination of driver and vehicle characteristics, therefore 'vehicle' and 'driver' will be used interchangeably in the following description to represent the vehicle/driver objects.

At the start of the simulation the route building module calculates one or two sets of shortest paths to each destination. The *Fixed* minimum-path tree is based on average travel costs representing the prevailing conditions according to the high flow levels used in the simulation period. These average travel costs may be set by the user, or alternatively, may be taken from a previous run of the SITRAS model. The *Actual* minimum-path tree is based on the free-flow travel costs at the beginning of the simulation, then the route building algorithm is called in regular intervals (currently every two minutes) to rebuild the current minimum paths to reflect the current flow conditions. The fixed minimum paths are updated only if there is a significant change in the flow generation levels. Information about the minimum paths is stored in the Link objects: each link has an array called *FixCost* containing the total fixed minimum cost to each destination, and another array called ActCost, storing the total actual minimum cost to each destination. This information is used by the vehicle objects to select their route during the trip to their preset destination.

Route selection occurs in SITRAS each time a vehicle enters a new link. At that moment, the CurLink parameter of the vehicle is set to the new link, and the SelectNextLink routine is called to set the NextLink parameter. Unguided drivers have an imperfect knowledge of the prevailing network conditions. Therefore the route selection routine in SelectNextLink for unguided vehicles uses the Fixed minimum-paths and Burrell’s simulation method (Burrell, 1968) is applied to calculate a *perceived* shortest route for each vehicle. This stochastic route choice method is combined in SITRAS with the drivers' familiarity with the network, which is linked to a given level of network hierarchy. The process is illustrated in Figure 5.

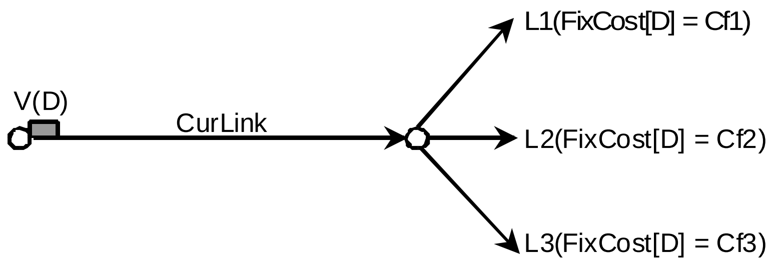

Figure 5 Illustration of the normal route selection process

When vehicle V travelling to destination D enters a previously selected link, this link becomes the vehicles current link (CurLink). The vehicle will then select its next link by comparing the total fixed costs of the possible following links that are connected to CurLink. The application of Burrell's method means that instead of using the true fixed cost stored in the link objects (C_{fi}), it will use a 'perceived cost' which is calculated by multiplying the true cost by a random number generated from a set distribution with mean equal to 0 and standard deviation equal to a user-defined value (Spread). NextLink will be the link which is perceived by the driver as having the lowest cost to its destination. This basic process is further refined in SITRAS so that first the driver attempts to select the next link from only those links which the driver is familiar with according to its set Network Familiarity parameter (eg. arterial road links only), and only if this selection is unsuccessful it will consider other links of lower network hierarchy.

Route choice in response to a VMS message: When a vehicle travelling on a link receives a message from a VMScontrol object, its NextLink parameter is set to the next link that the vehicle selected based on the normal fixed cost conditions when entering the link. The decision that has to be made is whether to keep this NextLink or to switch to another following link connected to the current link. This decision is based on a probability model developed specifically for this purpose. The structure of the decision-making process can be set up as follows:

- check if NextLink is part of the links affected by the message; if not, the vehicle can continue on NextLink, the process is finished – otherwise:
- for each potential alternative link
    - calculate the extra travel time (ETC) on the given link to Destination
    - calculate the probability to divert based on the driver/vehicle/trip characteristics
- if there are more than one alternative links, select the one with the highest probability to divert
- generate a random number from a uniform distribution in the range of 0 to 1
- if the number is in the range of 0 to probability, then set NextLink to the alternative link, otherwise keep the previously selected NextLink.

The two complex processes mentioned above – calculation of ETC and probability – are described in the next sub-sections.

Calculation of the Extra Travel Time to Comply (ETC): Extra time to comply (ETC) is defined by Bonsall and Palmer (1998) as the minimum extra travel time that a driver would experience *under normal traffic conditions* if he/she used the diversion.

When entering the link, the driver selected its next link as the one with the minimum perceived travel time to its destination. This value – which will be referred to below as *MinPerceivedCost* - can be used as the basis for comparison in calculating ETC. Note that this perceived cost is not necessarily the true minimum cost to destination.

Unguided drivers do not have a perfect knowledge of the prevailing network conditions, however, when the driver receives the VMS message, he/she will know that the links between the VMS site and the incident site are affected by the incident, therefore the prevailing conditions on those links are worse than normal.

This 'mixed' knowledge can be taken into account by using the following the process:

- a suitable set of link cost multipliers can be applied to the links affected by the message as suggested by Chatterjee and Hounsell (1998)
- the route building algorithm is called to calculate the total costs to Destination, based on this mixed link cost (ie. higher link costs for links affected by the message and normal costs for all other links)
- ETC can be calculated by comparing these new total costs to destination with *MinPerceivedCost*

As mentioned before, route choice is a step-by-step process in SITRAS: each time the vehicle enters a link, it selects the next link only. For this reason, route diversion cannot be considered as a one-off decision, but the vehicle needs to refer to this knowledge about the changed traffic conditions on the affected links, otherwise it may happen that the vehicle would return to the affected part of the network. This can be done in SITRAS by using a second link cost array (ActCost). It is also necessary to distinguish between vehicles that are aware and unaware of the changed network conditions:

- vehicles which received the VMS message will use the data from the total *actual* cost arrays to select their route to destination,
- other vehicles will continue using the total *fixed* cost for route selection.

This distinction can be implemented in SITRAS by defining a new flag in the vehicle Status parameter. The flag is set when a vehicle receives a VMS message. The route selection routine (SelectNextLink) can be modified so that if the flag is set, the vehicle will use the ActCost arrays, otherwise it will use the FixCost arrays for selecting its next link. As the difference between the actual and fixed costs is only at the links which are affected by the Message, there is no need to cancel the flag; once it is set, the vehicle can continue using the actual costs until it reaches its destination.

Based on the above considerations, ETC can be calculated as

$$ETC_i = L_i.ActCost[D]' - MinPerceivedCost$$

where

ETC_i	is the Extra Travel Cost of Link *i*
$L_i.ActCost[D]'$	is the 'perceived' total cost from link *i* to destination D based on normal traffic conditions but taking into account the influence of the incident on the affected links
MinPerceivedCost	is the minimum perceived cost to destination D based on normal traffic conditions.

The above calculation automatically ensures that the ETC of the link on which MinPerceivedCost was measured will be higher than that of any other alternative link (assuming of course that this original link is the one affected by the Message). Once ETC of each link is calculated, the link to be considered in the rest of the process is the one which has the minimum ETC:

$$ETC = Min(ETC_i)$$

Another issue to be considered in the modelling process is that, based on commonsense, and supported by data from Bonsall and Palmer (1998), the probability to divert is not a simple function of the absolute value of ETC, but rather a function of ETC relative to the total normal travel time. A driver is obviously more willing to accept an additional 5 minutes travel time if the total travel time is 60 minutes than if the total travel time is 10 minutes. As the total perceived time (cost) to destination is readily available in SITRAS, it appears more appropriate to use ETC in the following relative format:

$$ETC = Min(ETC_i) / MinPerceivedCost$$

Calculation of the probability to divert: Several authors (Wardman *et al.*, 1997; Chatterjee and Hounsell, 1998) used various forms of a multinomial logit model to calculate the probability to divert. We propose to implement the function in the following form after Wardman *et al.* (1997):

$$P_{ij} = \frac{e^{U_{ij}}}{\sum_m e^{U_{im}}}$$

where

P_{ij} is the probability that driver i selects alternative j from the choice set of m alternatives

U_{ij} is the utility of alternative j for individual i

The utility of an alternative j is related to relevant variables representing individuals' travel situations (X_j) and socio-economic characteristics (S_i):

$$U_{ij} = f(a_j X_{ij}, b_i S_i)$$

The usual form of the function is a simple linear combination of the variables used, although Wardman *et al.* (1997) found that a power function of the delay variable produces a slightly better model fit. However, considering the fact that the lack of calibration data seriously limits our possibilities to construct any realistic model, we propose to use the simple linear model. Similarly, the variables to be included in the model should also be selected in accordance with the difficulties associated with calibration. Variables suggested in the literature, their availability in SITRAS and our recommendation to include them in the proposed model are summarised in Table 1.

Based on the above considerations we propose to implement in SITRAS the following model for the calculation of link utility:

$$U_{ij} = a1\ ETC_j + a2\ MSG\text{-}C + a3\ MSG\text{-}S + a4\ D\text{-}FAM_i + a5\ VIS\text{-}Q_j$$

Table 1 Variables to be considered for the Utility function

Name	**Description**	**Availability in SITRAS**	**Include in model**
ETC	Extra Time to Comply – on alternative route, based on normal traffic conditions. The most important factor in the relationship.	Yes - calculated	Yes
MSG-C	The cause of the incident, indicated on the VMS message, eg. Accident, Congestion, Roadworks. Has an important effect on diversion probability.	Yes – user set for message	Yes
MSG-S	The seriousness of the incident, indicated on the VMS message, represented in the model by categories such as Low, Medium, High. Has an important effect on diversion probability.	Yes – user set for message	Yes
D-FAM	Driver familiarity with the network conditions. Has a significant effect on diversion probability.	Yes – vehicle parameter	Yes
VIS-Q	Presence/absence of visible queues on the affected/alternative links. May have an effect on diversion probability.	Yes – can be obtained from link status	Maybe
LNK-T	Network topology: whether or not the alternative link is a natural continuation of the route. May have an effect on diversion probability.	Yes – link parameter	Maybe
VMS-C	Credibility of the VMS system. May have a minor effect on diversion probability.	No	No
AGE	Age of driver. May have a minor effect on diversion probability. Evidence suggests that younger people are less inclined to comply with VMS advice.	No	No
SEX	Sex of driver. May have a minor effect on diversion probability. Evidence suggests that females are less inclined to divert.	No	No

Estimation of the numerical parameters of the Link Utility function: At this stage, no data are available in Australia for the calibration and validation of such models. Even the international literature contains only a very limited amount of numerical information about the model parameters. In order to obtain the required data, in 1999 and 2000 we have conducted an interview survey using the stated preference approach, in the Sydney Metropolitan Region. A total of 400 questionnaires were collected during the survey. Analysis of the data and development of a general route choice model in response to VMS are in progress, and the results will be reported in a forthcoming paper.

Summary and further work

A review of recent publications has provided a useful basis for developing an approach to modelling VMSs in the framework of simulating incidents and developing Incident Management Plans. Findings from previous studies have shown that the diversion rate in response to a VMS message is influenced by a number of factors, including the message content (cause, severity, route advice), the extra travel time (ETC) and driver characteristics (familiarity with the network, gender, experience with VMS). These findings indicate that VMS messages could be used as an active traffic management measure aimed at minimising the network-wide effects of an incident.

A microscopic transport network simulation model is the ideal tool to develop the appropriate traffic management strategy for any incident situation, because the factors determining the driver response to a VMS message (and hence, the diversion rate) are different for each driver, and most of these parameters are available in a microscopic simulation model. Based on findings from previous studies a general concept for modelling driver response to VMS in SITRAS, a microscopic transport network simulation model, has been developed and its implementation is in progress.

Several issues were identified for further research. While previous studies provided a better understanding of the factors influencing route choice behaviour in response to real time traffic information, the proposed models have serious limitations in predicting diversion rates under different conditions and in other countries. There is a need to develop more general models for prediction purposes in Australia and to calibrate such models based on local data. No information of this kind is available in Australia. Accordingly, we have conducted an interview survey to collect the required information in Sydney. The analysis of the data is in progress and the results will be reported in a forthcoming paper.

Previous studies have also shown that the extra travel time (ETT, the travel time difference between the alternative and the usual route under normal conditions) has a strong effect on the route choice behaviour in the presence of the VMS information. However, most previous studies were based on one or two fixed trips, therefore the results were relevant to the given fixed trip travel time. We believe that there is a strong relationship between the trip travel time and the ETT, which affects the probability of diversion. Thus, in the analysis of the data collected in Sydney, we intend to investigate the *combined effect* of the ETT and the travel time on the diversion rate in the presence of the provided information.

Vehicles that decide to stay on the affected route need also further investigation. Will they continue using the same route or would they reconsider their route at the next possible diversion point? While there is no indication in the literature as to how these vehicles are to be treated it is imagined that these vehicles should be given the chance to revise their decision at a later point in time.

Vehicles that do not comply with a VMS, as well as vehicles that approach the incident site from a route where no VMS is present can still be faced with a route diversion decision. This may depend on the flow conditions; levels of delay experienced, visible queues on the next selected link and availability of other possible alternatives.

These issues are investigated as part of our current survey analysis of driver response to VMS in the Sydney Metropolitan Region.

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