MODELLING DRIVER RESPONSE TO VARIABLE MESSAGE SIGNS WITH RGCONTRAM

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Abstract

Driver information systems are an increasingly important tool for traffic management. However, it is often difficult to quantify the benefits of these systems and to identify how the systems are most effectively used. Forecasting the network impacts of driver information systems requires an understanding of the ways in which drivers respond to information and this paper describes methods that have been used to identify driver response and incorporate it in RGCONTRAM, a dynamic traffic assignment model. The paper focuses on two types of driver information: variable message signs informing drivers of incidents; and variable message signs indicating car park space availability.

INTRODUCTION

Network management has an important role to play in reducing the impacts of traffic congestion. An important component of network management is the provision of information to motorists. Driver information systems are currently being widely implemented in Europe, North America and Japan. The main subject of this paper is roadside variable message signs (VMS) in urban areas and in particular those which provide motorists with information on network conditions and car park space availability.

It is often difficult to evaluate the benefits of driver information systems, such as VMS, and to identify how the systems are most effectively used. Nevertheless, network managers have to justify procurement decisions by estimating the network benefits that will be achieved. Network managers are also interested in effective use of information systems once they are implemented. Operational issues relate to deployment (such as where variable message signs are located to maximise their effectiveness), strategic procedures (such as the format of information that is presented to drivers) and tactical decisions (such as the specific course of action to recommend to drivers during an incident). A method is, therefore, required of predicting the network impacts of VMS in the typical circumstances in which they might be used.

Firstly, the paper discusses different methods of evaluating the network impacts of VMS. The paper then describes two studies where the network impacts of variable message signs are being evaluated through driver response surveys and network modelling.

EVALUATING THE NETWORK IMPACTS OF VARIABLE MESSAGE SIGNS

One method of quantifying the benefits of information systems is to establish the value of the information for users by asking how much they would be willing to pay for the information. However, this method is of only limited usefulness in the case of VMS, as there is no mechanism for motorists to pay for the information. Evaluation of network benefits can be carried out through before-and-after measurements, where the current provision of information is compared against the former provision of information under the same traffic conditions. This approach is discussed next. A traffic assignment modelling approach is discussed subsequently.

Before-and-after studies

The evidence from full-scale implementation of VMS in existing sites can be used to suggest potential benefits and operational procedures at other sites. Anderson *et al* (1996) describe the evaluation of a VMS system installed on the inter-urban road network in central Scotland. The VMS are used to display information on traffic incidents and events. An on-line monitoring and evaluation system has been set up, so that post-mortem calculations can be made of the network effects of VMS activation. The system measures changes in traffic patterns, due to the information on the signs, using data collected from automatic traffic monitoring units sited at key diversion points. Calculations of travel time savings and reductions in vehicle operating costs from a sample of VMS activations indicate a payback period of 2-3 years for the VMS system.

Dorge *et al* (1996) describe the evaluation of a VMS system installed in Aalborg (Denmark). The VMS are intended to produce a better distribution of traffic across the two routes (a bridge and tunnel) connecting Aalborg with Nørresundby. The signs can either display delay times for routes up to the bridge and tunnel or provide directional advice to specific destinations. The evaluation of the system involved estimating the degree of diversion, calculated as the percentage of vehicles intending to use the problem route which divert after passing an active VMS. Questionnaires and roadside interviews indicated the degree of diversion was about 25% for both types of information.

Axhausen *et al* (1994) describe the evaluation of a parking guidance and information (PGI) system installed in Frankfurt-am-Main. The results of a questionnaire survey indicated that there was a reduction in average search times for off-street parking at the busiest times, but little difference at other times.

In these examples, automatic traffic monitoring, supplemented by driver surveys, has been used to measure traffic performance and diversion rates. However, often with VMS, messages apply to abnormal, or even unique, events and it is impossible to measure the network performance under these conditions if messages were not implemented. Furthermore, VMS impacts on diversion rates are often modest and changes in link flows may not be able to be measured statistically, given normal traffic variability. In urban areas there are multiple diversion opportunities which further add to the difficulty in measuring diversion rates. Another obvious limitation of before-and-after studies is that results from one site are not always directly transferable to other sites.

Traffic assignment models

Traffic assignment models are commonly used for the evaluation of new road schemes and traffic management schemes. A good example is CONTRAM, which is designed to model the build up and decline of congestion (Taylor, 1990). The dynamic user equilibrium assignment in CONTRAM implies drivers have 'perfect information' about the future state of the network, which can be brought about only through repeated experience. Therefore CONTRAM is intended to model the traffic routes, link flows, etc. that occur on a typical day. When a major incident occurs, it is unrealistic to assume that drivers have 'perfect information' and re-route optimally, and it is also unrealistic to assume they do not make some attempt to avoid the resulting congestion, especially if they are forewarned. Therefore alternative techniques are required to model route choice in incident conditions.

CONTRAMI (Breheret *et al*, 1990) is a development of CONTRAM to predict the effects of drivers' self-diversion as a response to experiencing large queues. Incidents are modelled by reducing the saturation flow or capacity on relevant links, according to incident severity. The diversion logic is that drivers use their normal routes until they encounter an unexpected queue, the value of which is defined by the model user for each link. They may then re-route, dependent on their willingness to divert, and the attractiveness of the alternative (expressed in terms of extra cruise time).

MCONTRM is a development of CONTRAM, designed for use in the development of VMS deployment/message strategies (Hobbs *et al*, 1994). The user can specify: fixed diversion routes or allow free-routing at the VMS; the proportion of the traffic diverting (representing the effective strength of the VMS messages); and the timing of the display relative to the incident. In developing VMS strategies the impacts of an incident are modelled under three scenarios:

1. No VMS information given - all traffic uses non-incident routes;
2. All traffic has complete knowledge of incident – all traffic re-assigns to minimum cost routes;
3. Traffic which passes VMS has complete knowledge - proportion of traffic passing VMS diverts to fixed routes or re-assigns to minimum cost routes.

MCONTRM has been used for the Kent corridor network to calculate 140 fixed diversion plans. An appropriate plan can be selected by the operator in the event of a significant incident occurring. Further development of MCONTRM is underway to enable it to be used on-line, so that operators can test VMS plans immediately prior to activation.

RGCONTRAM is a development of CONTRAM to model traffic information systems (McDonald *et al*, 1995). 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 the time they arrive at junctions in the network, and can change route according to diversion rules. This simulation approach provides an improved capability for representing dynamic processes such as response to incidents. RGCONTRAM has been used to identify potential network impacts of urban VMS deployment in Southampton (McDonald and Richards, 1995). Like MCONTRM it has been used to identify optimum diversion proportions in different incident situations and to assist operators in selecting an appropriate VMS plan. The model user specifies destination-dependent diversion routes for traffic passing the VMS.

McArthur (1995) describes the method of modelling driver response to incidents and traffic information in the PARAMICS-CM microsimulation model. In PARAMICS-CM, vehicles can be re-assigned at key decision points (e.g. passing VMS) taking into account updated route costs. Route costs can be adjusted to take into account incident effects on specific links, advice from VMS, travel time uncertainty, etc. A change in route is dependent on the 'extra time to comply' (additional time on the alternative route compared to the original route) and parameters for drivers' patience and trust of information. For example, if the updated shortest route is only slightly better than the original route, then it can be ignored. Similarly, Jayakrishnan *et al* (1994) report that, in the DYNASMART model, diversion is dependent on whether the travel time saving on the alternative route (as indicated by VMS) exceeds a threshold.

The Institute for Transport Studies at the University of Leeds has used an interactive route choice simulator (VLADIMIR) to examine drivers' response to VMS (Bonsall and Merrall, 1996). Subjects were asked to 'drive' the simulator on a series of journeys through a replica of a real network, with and without incident information, and their junction exit choices were automatically recorded. The results have been analysed to produce logit models predicting the proportion of drivers who will use each exit of a junction according to the utility of each exit as a route to their destination. Parameters of the utility functions, which affected exit choice, included:

1. Journey time;
2. Whether the exit was a "natural continuation" from the entry arm;
3. Whether the exit had an unexpected queue;
4. The probability of the exit leading to the incident-affected location indicated by the VMS.

There is little reported work on the use of traffic assignment models to model the effect of PGI systems, although Polak and Vythoulkas (1993) outlined a model called RAPID, which was based on CONTRAM. Travellers are assumed to be either regular users or non-regular users. Regular users are assigned to optimum utility routes and parking facility choices. Non-regular users are assigned up to the parking facility entry ramp according to optimum utility routes and parking facility choices, except that no account is made of parking search time (which is a function of occupancy). If the intended parking facility is full then a new parking choice is determined for the non-regular user and it is re-assigned. To model PGI, non-regular users can be re-assigned at junctions downstream of VMS; regular users ignore the information.

The methods of modelling driver response to VMS described above include the use of fixed diversion routes, simple response logic and probability models. The fixed diversion routes approach requires the user to have a thorough knowledge of the network and to re-run the model with different diversion proportions. For VMS plan development, a suitable message then has to be identified that will result in the required diversion proportion. CONTRAMI, PARAMICS-CM, DYNASMART and RAPID have route choice logic within the models themselves allowing 'automated' use of the model to predict network impacts. However, it is important that the driver response logic reflects real behaviour and the logic in these models has had limited calibration. Probability models, if appropriately calibrated, provide a better alternative.

It is the objective of the work described in the next section to determine through surveys how drivers respond to unexpected congestion and incident messages in London and to incorporate the resulting driver response logic in RGCONTRAM. It is hoped to develop generalised response logic that can be applied in a wide range of urban networks. The research described in the next section is based on work in London, although similar work is also underway in Southampton (McDonald *et al*, 1998).

MODELLING DRIVER RESPONSE TO INCIDENT MESSAGES IN LONDON

VMS modelling is assisting in the evaluation of the VMS installations in inner London, which is being conducted as part of the CLEOPATRA project, a telematics project in the European Commission's Fourth Framework programme, involving strategies for collective and/or individual driver route guidance in six cities across Europe.

The London VMS system

Average traffic speeds in inner London (encompassing 14 of the 33 London Boroughs) are about 20 km/hr (DETR, 1997). 16,000 occurrences per year are recorded in the Metropolitan Police Congestion Log. Of these about one quarter are major incidents that are thought to warrant being brought to the attention of road users. A summary of incident causes for major incidents which occurred over a six month period in 1991 is shown in Table 1.

Table 1 - Major incidents in London and their cause

Severity Cause	Serious[1] (number,%)		Heavy[2] (number,%)	
Road Works (p)	206	(41)	333	(27)
Signal Faults (r)	39	(8)	152	(13)
Traffic Accidents (r)	109	(21)	299	(25)
Vehicle Breakdowns (r)	25	(5)	151	(12)
Other (p/r)	129	(25)	277	(23)
Total	508	(100)	1212	(100)

Notes:
1 "major disruption over wide area requiring immediate broadcast to public"
2 "very long queues and delays in locality, and on main roads through the area which should be brought to the public's attention"
p = planned event; r = random or unpredictable event

The London VMS system currently includes 30 signs, mostly located for inbound traffic on the major primary class "A" roads leading into central London. The system has been commissioned by the Traffic Control Systems Unit (TCSU). The Metropolitan Police are responsible for setting messages. Each sign can display a total of sixty characters (four lines by fifteen). Two basic message types are used: Immediate Warning messages and Advance Warning messages. The first line of text on the display panel is reserved for either the date/time of a problem or the problem location. The second line indicates the cause of the problem and the third or fourth line gives a recommendation about what to do or what to expect. A database of permitted words and phrases is maintained.

Typical message activation has been analysed from VMS message logs for 4 signs for the period November 1995 to May 1996. Most messages referred to events/traffic conditions in Central London and were activated on all four signs. Table 2 shows the breakdown of messages activated on one particular sign (Archway) by cause of problem and recommendation about what to do or what to expect. Of these 94 messages, 53 were Advance Warning and 41 were Immediate Warning. However, the figures in Table 1 indicate that unpredictable events cause about 60% of major incidents. This indicates that VMS are probably significantly under-utilised for unpredictable incidents.

Table 2 - Message activation at A1-Archway sign

What to do/ expect Cause	None	Diversion	Avoid area	Other	Total
Closed	3	13	16	5	37
Accident	0	0	4	1	5
Event	10	5	1	0	16
Road Works	2	0	0	2	4
Congestion	0	0	17	0	17
Other	8	0	0	7	15
Total	23	18	38	15	94

When road users pass Immediate Warning messages they are usually committed to the trip and the dominant response is a route switch. A wider range of responses are possible for Advance Warning messages, as some road users may be able to change their travel plans in a variety of ways to reduce/avoid the impact of the event. Although the use of VMS for Advance Warning may be highly beneficial, it is difficult to assess responses to it. Moreover, there are other media which disseminate this type of information. The scope for using VMS to display current information may increase with developments in traffic monitoring and incident detection. The CLEOPATRA study is, therefore, mainly focussing on Immediate Warning messages.

Driver surveys

Before investigating driver response to specific incident situations, a questionnaire survey was conducted to provide background evidence on drivers' opinions and requirements of VMS. The main finding was that drivers were interested in additional signs and for information to be updated more frequently. The results of this survey are described in more detail in Firmin *et al* (1997).

Driver response logic was required for modelling the effects of incident messages. The exit choice logit models developed at the University of Leeds were one option, but it was thought they would not be appropriate to London for the following reasons:

- the model calibration coefficients are likely to be specific to the Leeds network;
- the models are calibrated on the basis of exit choices made at every major junction. For most journeys in London, a driver is likely to pass only one VMS and to consider diverting infrequently, therefore use of the exit choice models would not be consistent with this situation.

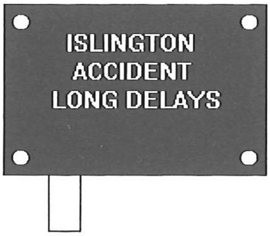
The use of an interactive travel simulator was discounted because it would have been very expensive to build a realistic replica of a London road network. Stated preference questionnaires have been used instead. Similar questionnaires have successfully been used to gather data on drivers' response to VMS in previous studies (e.g. Wardman *et al*, 1997). An advantage of using stated preference questionnaires, as opposed to a travel simulator, was that the questions were designed to relate to drivers' actual journey, rather than a hypothetical journey. Hence, there was greater confidence that drivers would provide realistic responses.

Two thousand self-completion questionnaires were distributed to drivers travelling on the A1 towards central London, at the Archway Junction, on 11 December 1997. A VMS sign is sited immediately upstream of the Archway junction facing drivers approaching central London from the north. For southbound traffic, the two main exits at the junction are the A1 and the A400. An analysis of the destinations of traffic using these two exits, based on CONTRAM modelled routes for a normal morning peak, has shown that it is viable for a significant amount of traffic to switch between the A1 and A400 to reach their destination. Before conducting the final survey, two pilot surveys were conducted, in which different questionnaire formats were tested.

Each questionnaire asked drivers for the following information:

1. Characteristics - sex, age and annual mileage
2. Details of the journey being undertaken - origin, destination, total journey time, familiarity with route, marking of the route on the map supplied with the questionnaire.
3. Scenarios for unexpected congestion – (i) whether on arriving at the Archway junction and observing a stationary queue of traffic on their downstream exit they would divert, and (ii) what amount of significant increase in their journey time they would need to experience up to Archway junction (with traffic continuing to move very slowly) for them to divert.
4. Scenarios for messages shown on the Archway VMS – five message scenarios were included in each questionnaire. An example is shown in Figure 1.

If, as you approached Archway junction, you had seen a VMS saying:



Would you divert from the route you have marked on the map ?

Yes, I would divert
(please give details of route below)
Yes, but not until encountering further problems
(please give details of route below)
No, I would not divert

Please describe diversion route below

Figure 1 - Example of message scenario

One half of the two thousand questionnaires was distributed to drivers of vehicles stopped in an A1 traffic lane and the other half to drivers of vehicles stopped in an A400 traffic lane. The only difference in the A1 and A400 questionnaires was that the locations referred to in the incident messages were modified for relevance to each road. The experimental design, which was used for the message scenarios, included three variables (location, cause of problem and what to do or what to expect), each with four levels. In each questionnaire, the same cause of problem was indicated in all scenarios, but an immediate, near, medium and far-distance location was indicated and the what to do or what to expect was varied. This led to eight different questionnaire sets for the A1 and eight sets for the A400.

Network modelling

A CONTRAM network of 1,600 links is available for a 100 square kilometre area of inner north London, which incorporates the Archway VMS and the southbound downstream routes. The part of London included in the network is shown in Figure 2. The modelling process being used for incident evaluation is illustrated in Figure 3. CONTRAM is run to generate routes used in normal conditions. RGCONTRAM is then run twice: first to model the effect of the incident without VMS and then with VMS. In both cases, the incident is introduced during the study period affecting traffic queues and delays. Vehicles set off using the CONTRAM routes, but can divert from these routes according to their experience of unexpected congestion and incident information. Evaluation is based on a comparison of the driver/network performance in the three different model runs.

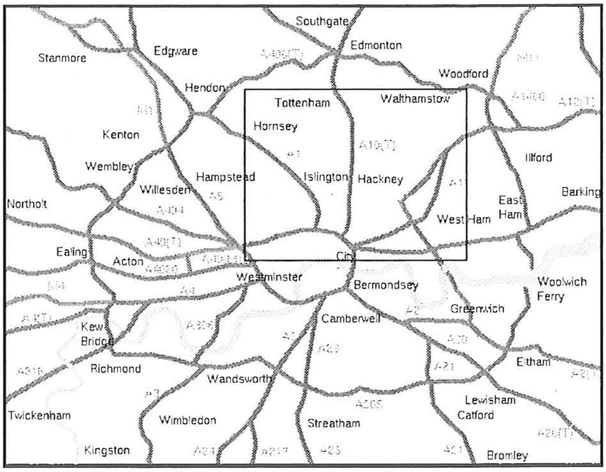


Figure 2 - Inner North London CONTRAM network

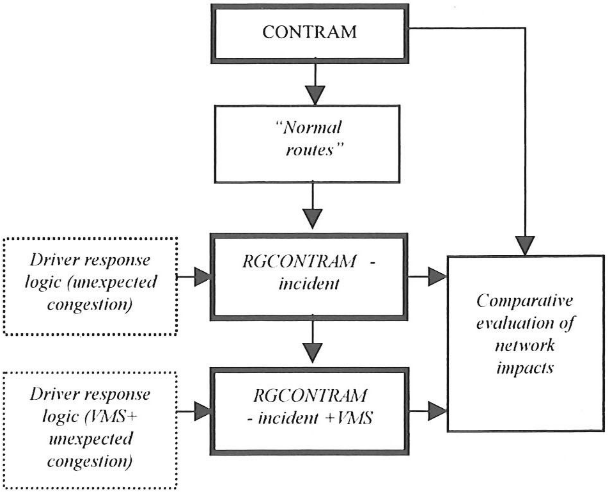


Figure 3 - Modelling process for incident evaluation

Driver response logic is being obtained using the data from the stated preference study. The data is being analysed through the development of statistical models (logistic regression models) relating the probability of diversion to driver, journey and message characteristics. Analysis so far has shown that drivers are unable to predict travel times in incident conditions. Therefore, it will be assumed that drivers are only aware of travel times in non-incident conditions and that a diversion decision is based on this knowledge as well as the incident message (or unexpected congestion). The questionnaire data is currently being prepared for model calibration.

In conjunction with the driver response logic, a method for identifying an alternative route is required for each incident-affected driver passing an active VMS. The alternative route should avoid the influence of the reported incident. The obvious option is to prevent use of the incident link(s). However, the alternative route may then be very similar to the normal route with a short loop round the incident link. The approach adopted in RGCONTRAM is to apply travel time multipliers to links between the VMS and the incident. 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 (i.e. amount of traffic using link that also normally passes the incident link) and incident severity. After identifying an alternative route, the normal journey time between the VMS and destination on the route is calculated using CONTRAM travel time information and the driver response logic is used to estimate the probability of diversion. Monte Carlo simulation will be used to identify whether a driver diverts or not.

Some initial model runs have been carried out for the Inner North London network. Simple assumptions have been made about driver response. The effect of a one hour incident during the morning peak blocking one lane of the A1 (southbound) at Highbury has been examined and results are shown in Figure 4. This shows that if drivers stay on their normal routes (fixed scenario), the drivers passing the VMS and using the incident link experience large delays (about 50%), but other drivers are hardly affected. In the unlikely circumstances that drivers have perfect knowledge of network conditions (optimum scenario), then no category of driver experiences significant delay. Figure 4 also compares the effects of different diversion proportions. Drivers passing the Archway VMS were diverted to fixed diversion routes. The results indicate that it is better if 50% divert rather than 10% or 30%. The next step is to use the calibrated driver response logic to examine a range of incident scenarios.

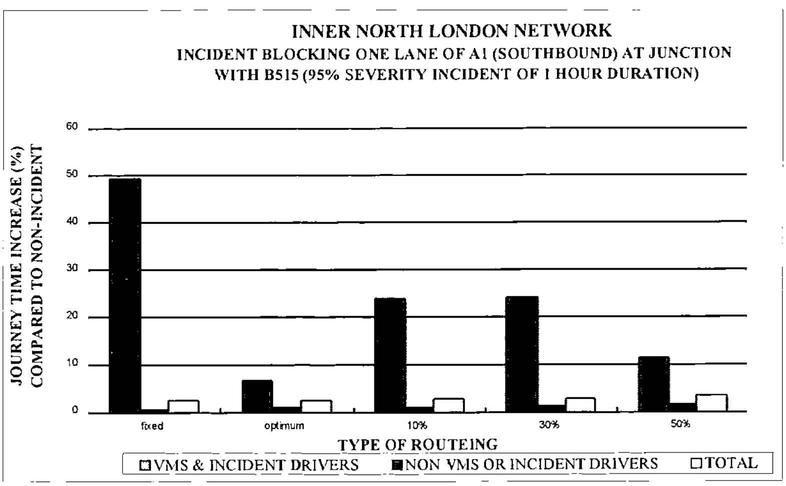


Figure 5 - Initial modelling results

A field demonstration will be conducted to examine the quality of the model predictions. The demonstration will involve a real incident occurring within the Inner North London network. Automatic monitoring facilities (UTC) and revealed preference questionnaires of drivers, who are affected by the incident, will be used to measure traffic conditions and diversion rates and compare them with the modelled results. The overall results of the study will contribute to an economic evaluation of VMS effectiveness and to the production of message guidelines.

MODELLING DRIVER RESPONSE TO PGI INFORMATION

Modelling of driver response to PGI is being conducted as part of a project examining the effectiveness of PGI systems in improving efficiency of the parking search process and the allocation of available parking spaces. The work involves the enhancement and application of RGCONTRAM to study PGI effectiveness in a range of scenarios. Surveys have been carried out to collect parking behaviour data and the resulting parking decision models will be implemented in RGCONTRAM.

Network structure

Parking facilities can be added to traffic assignment models by substituting conventional zone connectors with a sequence of links, which represent access to parking, the parking activity itself and egress. Figure 5 illustrates the network design.

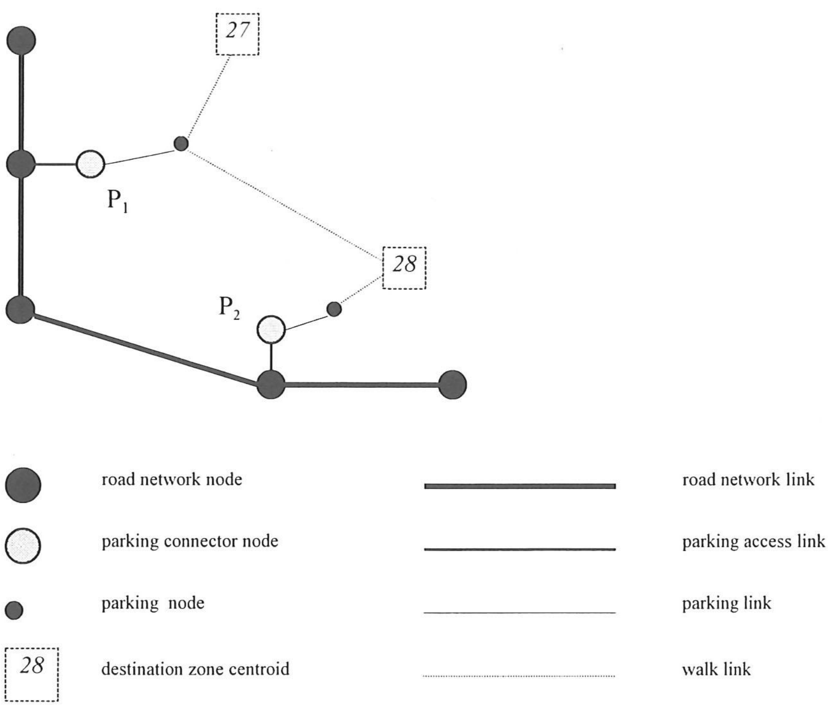


Figure 6 - Network design for modelling parking

The parking access link is connected to the real road network and can be used to model delay between the road network and the parking entry ramp. The parking link represents the parking activity itself and in particular the generalised cost of parking. The cost would include a number of components such as time spent searching for a space, cost of parking and uncertainty about space availability. The search time is a function of the occupancy. A search time-occupancy function needs to be specified for each parking link and the occupancy of each parking link would need to be updated at every arrival and departure, so that subsequent arrivals experience the appropriate delay in searching and waiting for a space. The cost structure would vary depending on whether the parking link represents an off-street or on-street facility, or a public or private facility. The walk link represents egress costs, which are usually related to the walking time between the parking facility and the destination zone.

The connection between parking links and destination zones can be represented by a table of parking costs with parking facilities in one dimension and destination zones in the other dimension. If a parking facility is far from a destination zone then its use can be prohibited for travellers to that zone. An existing traffic network model of Southampton is being adapted for use in the study by adding parking and walk links to the city centre part of the network and constructing a parking costs table.

Modelling process

An approach to modelling PGI by Polak and Vythoulkas (1993), based on CONTRAM, was described earlier. The criteria for parking choice depended on whether the driver was a regular or non-regular user. It was assumed regular users have complete knowledge of parking occupancies and search times and non-regular users have no knowledge. In the current work, surveys are being carried out to gain a better understanding of parking decisions and to develop parking choice models. The behavioural framework is as follows:

1. a joint choice of parking facility and route is made before departure;
2. after departure, choice of parking facility and route is only reconsidered when unexpected conditions (PGI sign, full car park) are encountered.

The parking choice models are to be incorporated in RGCONTRAM and used in PGI evaluation. Figure 6 illustrates the RGCONTRAM modelling process. Parking choice is incorporated in CONTRAM by modifying the assignment logic so that a combined choice of route and car park is made based on factors found to be relevant in the parking behaviour surveys. RGCONTRAM is used to model the effect of PGI. In RGCONTRAM, each driver starts off with their route and car park from the CONTRAM run. Drivers reconsider their choice of parking facility and route when passing a PGI sign or arriving at a full car park. To examine the effect of PGI, two or more RGCONTRAM runs are carried out. For example, in scenario 1, it could be assumed that the PGI signs are switched off and in scenario 2 they are switched on.

Parking decision models

The Institute for Transport Studies at the University of Leeds has designed an interactive travel simulator (PARKIT) for examination of drivers' parking decisions, including their response to PGI signs (Bonsall *et al*, 1998). Subjects were asked to 'drive' the simulator on a series of journeys through a hypothetical network, with and without PGI information, and their junction exit choices and parking decisions were automatically recorded. 50 surveys have been carried out in Southampton and 46 in Kingston-upon-Thames.

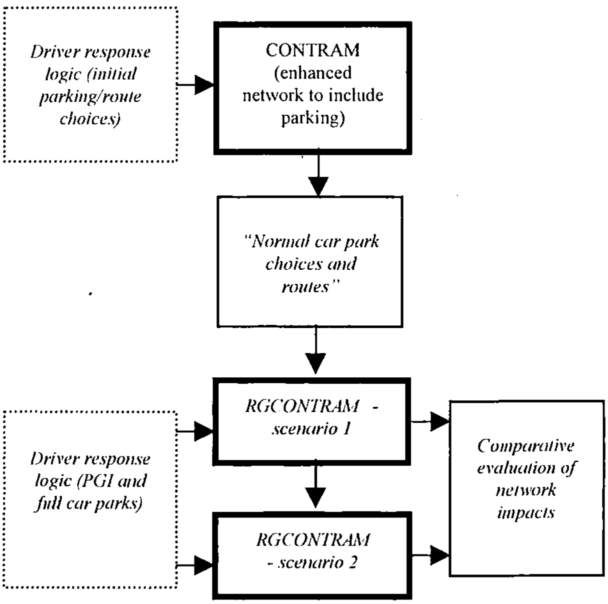


Figure 6 - Modelling process for PGI evaluation

Parking prices, expected risk of waiting to park, waiting times and PGI information were varied between each subject's journeys. To examine the effect of prior knowledge, the amount of information given to the subjects was limited on the first journey, but complete for subsequent journeys. Other factors that were varied included travel time, walking time, journey purpose and car park size. There are numerous other factors that may influence parking behaviour, which could not be examined using the simulator, but it was hoped that the simulator data could provide an understanding of the main factors and especially the effect of PGI information. The simulator data is currently being analysed at the University of Leeds. Probability models are being developed predicting combined parking and route choices as a function of their utilities.

A questionnaire survey has been conducted by the Centre for Transport Studies (Imperial College) in Kingston-upon-Thames to collect information on attitudes, preferences and responses to parking and PGI signs. This is to be used to characterise the demand in the Southampton network so that the parking choice models can be appropriately applied.

SUMMARY AND CONCLUDING REMARKS

Dynamic traffic assignment models provide a powerful method of examining the network impacts of VMS. However, existing models are limited in their representation of driver response. In some cases, fixed diversion proportions have been assumed and in other cases simple logic has been used with limited calibration.

In the CLEOPATRA project, RGCONTRAM is being used to predict the network effects of incidents in London and the benefits that can be obtained through the use of VMS. The paper has described a method of calibrating driver response logic from questionnaire surveys and the way in which the driver response logic is going to be incorporated in RGCONTRAM. The driver response logic will enable the impacts of different incident scenarios to be tested for a network of Inner North London. Model predictions are to be validated through on-street measurements of traffic performance and diversion rates for an actual incident.

The paper has also described work being carried out to model the impact of PGI systems. Surveys have been carried out to obtain an understanding of the factors underlying drivers' parking decisions both before and after they receive information. The survey data is currently being analysed and the parking choice models that are developed will be used in RGCONTRAM to test the effectiveness of PGI systems for a range of traffic situations and information types.

The results of these studies will contribute significantly to the evaluation of the VMS systems under investigation, as well as providing valuable findings relating to VMS in general. It is hoped that the driver response logic being developed as part of these studies is not only applicable to the networks and models currently being studied, but will have wider application.

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