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EFFECTS OF INCIDENTS ON NETWORKS WITH VARIABLE MESSAGE SIGNS

by

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ABSTRACT

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Variable Message Signs (VMS), which provide traffic information to drivers, are being used increasingly to improve network efficiency and reduce congestion. As with other technologies of traffic information, the effects of VMS are very dependent on behavioural responses of drivers. It is very important to understand each VMS strategy before its implementation in a VMS system. An inappropriate setting may lead to a loss of credibility with motorists and thus for them to cease to be effective. In this research, the routing effects of VMS are investigated using modelling and empirical measurements in order to estimate the value of strategies in incident situations.

Network modelling offers a controlled environment in which the potential effects of VMS can be studied in a variety of incident/VMS scenarios. The modelling results are derived using the 'single-day' version of the RGCONTRAM model based on the Southampton network. Two key performance measures have been used to assess the effectiveness of a VMS strategy: The journey time savings of network drivers and the journey time savings of incident drivers. In general, it was found that incident drivers benefit from diversion, even those incident drivers who do not divert, because of reduced congestion on the incident route. However, there can be substantial disbenefits to non-incident drivers, particularly for those travelling on diversion routes. The results describe the effects of VMS information, which vary significantly with incident severity, incident duration, traffic demand, VMS duration and the diversion routes available.

From August 1st, 1999 to December 20, 2000, information on incidents occurring in Southampton, the VMS strategies used, and traffic data over the network have been collected and analysed. All the major incident cases on the four main arterial in Southampton have been studied. It was found that drivers make a wide range of diversion decisions including both 'early' and 'late' diversion at VMS. Early diversions were defined as those which occurred shortly after the sign was seen. The results of incident case studies indicated that 0-34% of relevant drivers made early diversions at VMS. The variations were dependent on the number and the quality of viable diversion routes, messages displayed and peak types. Such early diversion can be entirely the result of the information provided, because no abnormal queues would have been encountered by drivers before the diversion. Also, late diversions were widely found in the incident cases studied. In most incident cases, the late diversion rates were found to be higher than the corresponding early diversion rates, which indicated that drivers were more likely to divert after their acquired VMS information was confirmed by the observed queues. An application of the implications of these post mortem results on the model findings has been made.

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1 Introduction

1.1 Background

Improvements in computer and information technology have made it possible to provide dynamic traffic information to drivers and so lead to reduction of the impact of incidents on road network efficiency. A number of major research and development programmes and projects involving traveller information systems have been taken place throughout the world. These include, in Europe, the DRIVE initiative and Berlin's LISB system. In the USA, under the umbrella of the IVHS steering committee, projects include Orando's TravTek, California's PATH. And in Japan, the Road/Automobile Communication System and the Advanced Mobile Traffic Information and Communication System are major trials. In the UK, RTA and ITSWAP are taking research forward, whilst TrafficMaster is a world leader in commercial systems.

The provision of real-time information to travellers will be likely to lead to more efficient distributions of traveller to routes. For the individuals, traveller information systems can lead to more effective route choice and help to reduce anxiety and stress associated with way-finding and navigating through the network. For the system as a whole, if enough travellers use advanced traveller information systems there may be significant reductions in travel time, delay, fuel consumption, and emissions.

Variable Message Signs (VMS) are being increasingly used to provide traffic information and/or guidance to all drivers, irrespective of in vehicle units. (In-vehicle systems currently have limited scope due to their low market penetration). Roadside information has considerable scope for network management in the short term, as it is accessible to the entire motoring population. Like other technologies of traffic information, the effects of VMS are very dependent on drivers' behavioural responses. Inappropriate use of VMS may lead to them losing credibility with the motorists and thus ceasing to be effective. Therefore, it is very important to understand the potential impacts of VMS. In this research, the routing effects of VMS will be investigated based on modelling and measured results.

1.2 Objectives

This research is concerned with the extent to which roadside traffic information influences route choice so that existing networks can be used more efficiently. The broad research issues are to understand whether or not traffic flow rates on the network with VMS are significantly different from those without VMS, i.e. to what extent VMS affects drivers' route choice and hence network efficiency. More specifically the objectives of this research are:

- To identify the main factors which influence the benefits/disbenefits of VMS and explore the potential network effects of VMS in different traffic/incidents conditions.
- To study driver's diversion responses to VMS information in real traffic conditions.
- To investigate the impacts and benefits of dynamic information disseminated via VMS within urban areas more generally.

1.3 Method of Approach

Network modelling and field measurements are the main approaches used in this research. Firstly, network modelling was used to explore the potential network benefits of VMS. The most common method for evaluating network performance has been network modelling as it offers a controlled environment to explore the potential network effects of traffic management strategies in a variety of scenarios. In this research, the 'Single-Day' version of RGCONTRAM has been used to model the effects of VMS. The potential journey time effects on incident drivers, non-incident drivers and the total network drivers were investigated, compared to the 'do nothing' scenario.

Secondly, empirical measurements were conducted to investigate drivers' diversion response to VMS information in real traffic conditions. Southampton was selected as the field study site for its comprehensive coverage of VMS signs and extensive monitoring system of detectors. Traffic data were collected using the newly developed SCOOT U06 and U07 messages which produce flow, speed, occupancy, switching ratio and headway ratio at half and five minute intervals. Drivers' diversion response to VMS and the relationship between diversion rates and

VMS messages displayed were investigated for incident case studies, based on the analysis of traffic data and VMS strategies for each incident scenario.

Finally, the measured diversion rates from real incident scenarios were fed into the RGCONTRAM model to produce quantitative network benefits of VMS, and to estimate the impacts of VMS on network efficiency.

1.4 Layout of the thesis

The thesis consists of eight Chapters. The introduction of the background, objective and method approach used in this research are in the first Chapter. A review of theoretical and research of VMS is undertaken in the Chapter 2, with the existing VMS applications and the approaches used for the evaluations being critically reviewed. Also, a review of modelling approaches currently used has been made at the end of Chapter 2.

The model requirements for this research are described in Chapter 3. The features of a typical simulation model are discussed generally and the choice of the single-day RGCONTRAM model is explained. The structure, input and output of the RGCONTRAM model are described at the end of this chapter.

In Chapter 4, the network effects of VMS are described. The incident scenarios selected for the modelling and the associated assumptions are explained and the analysis and interpretation of the modelling results are presented.

The network monitoring and data collection process for the 'post mortem' studies in Southampton are described in Chapter 5, and the results of the incident case studies are presented.

In Chapter 6, the results of the analysis of driver's responses to VMS in real conditions are described. In this Chapter, the site description of the incidents, detectors and VMS strategies used are presented. The analysis of driver's responses to VMS is based on the measurements of traffic flow, speed and occupancy across relevant parts of the network.

In Chapter 7, the assessments of VMS impacts on network efficiency are described. The assessments used the incident cases collected in which the diversion rates were based on the measurement results. The network benefits of VMS were calculated by using RGCONTRAM model.

Chapter 8 provides conclusions drawn from results achieved in this research and recommendations for the further research.

2 Literature review

2.1 Driver information systems

2.1.1 Information need for drivers

Information is important to drivers, especially en-route traffic information. Once having begun a journey, a driver may encounter congestion which is caused either by heavy demand or by the occurrence of an incident. When no real-time information is available, drivers' decisions as to whether or not to divert have to rely on their own judgement based on the observation of the change in traffic conditions and their knowledge/experiences. Driver's knowledge of traffic conditions is limited and imperfect, because of the limitation of what they can observe. Providing information about the current or future conditions concerned (e.g. the cause of congestion, the road links affected by the congestion, queue length, travel time or delay) will reduce a driver's stress in their route choice decision and will make it possible for drivers to make informed decisions (Adler et al, 1998).

The information on routes can be categorised into either descriptive or prescriptive (Van Berkum et al, 1999). Descriptive information provides drivers with information about the state of the network or transport systems. Prescriptive information tells drivers what to do. This type of information is similar to a co-pilot who directs the driver through the network. Descriptive and prescriptive information may also be mixed. Prescriptive information may be either followed by the driver or ignored, depending on its credibility and relevance. Descriptive information does not lead to compliance, but leaves it to the traveller to process. Both types of information may lead to adjustment of the knowledge and expectations of the traveller.

Route guidance refers to prescriptive information designed to direct a driver along a prescribed path to a desired destination (Adler et al, 2000). Link-to-link instructions are provided to the traveller through visual and /or auditory interfaces. In static route guidance systems, the best paths are identified based on a predetermined set of network attributes and not connected to any real-time information sources. Dynamic route guidance systems are capable of incorporating real-time information sources to provide more informed guidance to drivers. The advantage of using route guidance is that drivers do not need to be familiar with the network layout or travel conditions. They can rely on the routing systems to provide an efficient path through the network. A potential disadvantage of these systems is that they may suggest routes that do not coincide with the drivers' travel objectives and preferences.

Traffic information, which is descriptive in nature, can be used to inform drivers of prevailing traffic conditions. Included in this category are reports on delays, incidents, and prevailing speed on links and at interchanges in the network. With this information, drivers are required to independently process the information and develop their own routing strategies.

For assistance with en-route navigation and wayfinding, drivers can acquire route guidance and traffic information through systems deployed at the roadside (e.g. variable message signs and traffic and travel information broadcasting), or in-vehicle (e.g. in-vehicle routing and navigation systems) (Adler, 2000)

2.1.2 Traffic and travel information broadcasting

The range of Traffic and Travel Information (TTI) broadcasting include traffic announcements (short and long) every day, supported by TV and Teletext information and service phones. Recently this has been augmented by newly developed services using the Internet. In general, TTI broadcasting provides free information service to users, which make it the most widely used information sources to drivers (Kopits et al, 1998).

A defining characteristic of travel information disseminated by the TTI broadcasting is that it is targeted generally rather than at the particular requirement of individuals (McDonald et al, 1997). This has a number of implications:

- Irrelevance. Information may be considered irrelevant to many travellers. To those irrelevant public, such announcements might be intrusive, repetitive and irritating.

- Informs rather than advises. Usually travellers are informed of traffic conditions without being instructed or prescribed how to respond.

- Response of others. An individual may respond taking into account how they perceive others are likely to respond (i.e. despite roadworks a motorist may use their usual route because they assume other motorists will divert).

2.1.3 Variable Message Signs (VMS)

Traditionally, road maps and static direction signs have been the main methods by which drivers have selected and followed routes to their destinations. However, improvements in collection of on-line traffic data and communication/computing technologies have led to the introduction of Variable Message Signs (VMS).

Variable Message Signs (VMS) are information devices which display messages in the form of either text, graphic or combined. VMS provide information about recurring congestion due to heavy traffic demand and non-recurring congestion caused by incidents such as accidents, roadworks, vehicle broken-down, weather-related problems and other events. They may also be used to confirm that conditions are 'normal' in some way, or display more general messages to indicate to drivers that the signs are working, but no adverse traffic conditions are occurring. Variable Message Signs are also referred to as Changeable Message Signs in some publications (Pouliot et al, 1993; Vick et al, 1998).

Generally, a VMS unit consists of four components: 1) display board, 2) monitoring equipment, 3) communication network, 4) control centre. VMS can be classified according to their application areas as showed in Table 2.1

Table 2.1 VMS systems by application areas (Wei, 1998)

VMS scale	Examples
Point based	Parking guidance. This is intended to increase the efficiency or utilisation of the parking facilities; reduce congestion in and near car park; reduce driver frustration caused by prolonged searching for a parking place, and make the area more appealing to visitors.
Link (highway section) based	Congestion warnings, dangerous weather warnings, incident advice, detours required due to roadwork, speed limit notices on a specific highway or segment. These make travel safer, reduce travel time and improve the highway operation.
Corridor based	Incident management, route guidance and diversion on a corridor consisting of several parallel and other connected highways.
Region based	Incident management, travel pattern control, and route guidance in a metropolitan or wider area. This is used mainly for travel demand control in the region and to improve traffic conditions for the whole area

VMS are being increasingly used to provide traffic information and/or guidance in many countries. Many researches and projects have been reported. These include the ROMANSE project in Southampton, UK (McDonald et al, 1995; 1996), the CITIES project in Paris, France (Durand-raucher et al, 1995; 1996), the VMS system in Arlington, USA (Bension, 1996), the QUO VADIS project in Aalborg, Denmark (Mammar et al, 1996), and the FEDICS system in Central Scotland (Anderson et al, 1996). Currently, VMS mainly serve the following purposes:

- warning adverse traffic conditions (advance or immediate);
- route advisory;
- parking guidance;
- guidance for special events.

2.1.4 In-vehicle systems

The level of sophistication of in-vehicle systems is highly dependent on the communication capabilities. Three categories are identified:

(i) Autonomous navigation systems

Autonomous navigation systems provide enhanced way-finding capabilities over traditional navigational aids (e.g. maps, signs). Drivers input the origin and destination at the start of a trip and an on-board microprocessor tracks the vehicle's passage using one or more of the range of technologies (e.g. GPS, dead reckoning). Information may be passed to the traveller in a series of ways, the most common being either a simple direction arrow or map display. Route advice criteria include minimum journey time. The limitation of this type of system is the absence of dynamic information on network conditions, although the database can contain link journey times that vary by time of the day, according to an estimate of recurrent congestion. Autonomous navigation aids are likely to be most useful for new or infrequent journeys (Phelps et al, 1997).

(ii) One-way communication systems

Information is received by the vehicle from a control centre. The information may be sent out on an area or point basis via beacons. The information may be updated regularly from a range of sources, and all vehicles passing a beacon in the time between updates receive the same information. An optimum route, as with the autonomous calculation, can be determined through on-board processing, but with the benefit of knowledge of current traffic conditions. However, the cost of such units is high and more information is required than is at present generally available, and the central control will be unaware of the routes chosen by drivers (based on on-board recommendations). Consequently, as the proportion of guided/informed drivers increases, the routes selected as a result of the information/guidance could result in a reduction of efficiency and a loss of credibility.

RDS-TMS (Radio Data System-Traffic Message Channel) is being widely introduced in Europe and has been agreed as a world standard. RDS enables digitally–encoded data to be inaudibly superimposed on the stereo multiplex signal of a conventional FM radio broadcast (Bright and Ayland, 1991; Kopits et al, 1998). A specialised receiver is required to decode traffic messages, which can then be presented as text or synthesised speech. The types of messages provided are likely to be similar in principle to local radio and roadside VMS (i.e. descriptions of latest traffic conditions) since the individual circumstances of the end users are unknown.

Traffic*master* is one of the most advanced systems of this type generally available, although the driver receives limited information with which to make a complete decision (McDonald and Lyons, 1996). Trafficmaster uses paging technology and low-power radio transmitters to deliver encrypted real-time information on traffic speeds and congestion to its subscribers. With Traffic*master* the driver can refer to a map of the motorway and trunk road network in which they are travelling. Spot speeds are collected automatically on motorways through a network of speed detector mounted above the roadway on gantries and over-bridges at approximately 2-mile intervals.

(iii) Two-way communication system

Two-way communications enable information from the vehicles to be passed to the control centre. This allows guided vehicles to return information on their journey times, thus providing an internal system database, or the enhancement of other centrally held information. Decisions on routes are calculated centrally, thereby incorporating predictions of changes in network conditions.

Examples of this type of system are the Siemens ALI-SCOUT systems piloted in London (AUTOGUIDE) and Berlin (LISB) (McDonald and Lyons, 1996). These systems utilise a system of infra-red beacons strategically located on the road network and in-vehicle units, with an in-built dead-reckoning capability for navigation between beacons. Two-way communication between the in-vehicle units and the beacons allows information on the network conditions to be exchanged between the vehicle and a database of real-time network condition. Routing advice messages are provided to the driver according to optimal route calculations. Another example of a dynamic route guidance systems is TrevTek in Orlando (Rillings, 1991; Inman et al, 1996). Tests were conducted in Orlando, Florida, between 1991 and 1994 to evaluate the performance and usefulness of the navigation system. The Trevtek system had three main components: 1) Traffic Management Contre (TMC); 2) TrevTek Information and Service Centre (TISC); 3) In-vehicle System. TrevTek was evaluated by gathering data from several experiments and tests, each with different objectives and evaluation methodologies.

2.1.5 Comparison between roadside VMS and in-vehicle systems

VMS is an off-vehicle device which provides traffic information/guidance to influence a driver's route choice decisions. VMS systems have a number of advantages over in-vehicle systems. VMS provides information to all drivers passing the signs. Secondly, VMS information is free compared to in-vehicle systems where drivers have to pay for the in-vehicle device and usually the service. The main disadvantage of VMS system is that it can not provide route guidance to individual drivers with different origins and destinations.

In-vehicle guidance systems enable individual drivers to be influenced depending on their origin and destination and possibly their route selection criteria. By co-ordinating the dissemination of the guidance information, the control system can help to ensure that a local congestion problem is not simply shifted to another part of the network. The other main advantage of such systems is the possibility for equipped vehicles to generate data on prevailing conditions. However, in-vehicle guidance systems have a number of disadvantages over VMS systems. Firstly, the behaviour of only a proportion of the population will be influenced. Ownership may be limited by the cost of in-vehicle units, consumer confidence in the system, and perhaps a perception of diminishing returns as the proportion of equipped drivers increases. A second disadvantage of in-vehicle guidance systems relative to VMS, is the potentially greater cost to install the infrastructure, the in-vehicle devices and route guidance services (Bonsall, 1997).

While VMS systems are operated by public authorities in order to increase safety, improve traffic efficiency and environment, in-vehicle route guidance services are mostly operated by the private sector. They are intended to help individual drivers and fleet operators to prepare and undertake their journey efficiently. Thus, whilst VMS influence traffic in general, private systems focus on providing services to meet the needs of individual drivers/operators (Fritz et al, 1999). The incentives for private actors are generally of commercial in nature and have to provide 'advantages' to the individual user in order to create the willingness to pay for information and services.

2.2 Existing VMS systems

2.2.1 Introduction

Variable message signs have been in existence for many years, but recently their numbers have increased noticeably. The use of electronics has provided more flexibility in sign design and operation, and the widespread availability of communications has provided an infrastructure within which variable signing systems can be easily implemented. Now, VMS are being used for many purposes including traffic information, route guidance, parking guidance, speed control, public transport information and environmental information. In this section, VMS applications to provide traffic information/guidance are reviewed.

2.2.2 VMS applications

There are many VMS currently being used to provide traffic information and route guidance worldwide, especially in Europe. In this section, some VMS applications are reviewed including VMS in Aalborg of Denmark, Bristol, London, Southampton and Central Scotland of UK, Paris of France, Turin of Italy, Valencia of Spain, and the interurban highway network between Osaka and Kyoto of Japan.

VMS in the Paris region

The SIRIUS real-time traffic control and information system has been installed on the Paris region's freeway network (Haj-Salem et al, 1995; Yim et al, 1996). There are 200 VMS on the peri-urban motorways (arterial road and other ring roads) which up to February 1996 displayed congestion (queue) length messages. From February 1996, travel time to specific destinations was displayed. There are also about 200 VMS on the corridor Peripherique (comprising two closely-spaced parallel rings, the Boulevard Peripherique (BP) of motorway type, and the Boulevard des Marechaux (BM) which is signal controlled. For both networks, an expert system is used to determine message strategies that ensure consistent and coherent information provision.

Motayka & James (1994) and Durand-Raucher & Santucci (1995) described the results of early evaluation work of the SIRIUS east network. Questionnaires showed that, in general, VMS messages were well understood and considered to be reliable and useful. Travel times were preferred to queue length messages. Durand-Raucher et al (1996) updated the evaluation work for the SIRIUS east network. From measured diversion rate and estimated changes to queues, flows and travel times, it was estimated that the cost-efficiency ratio of SIRIUS is between 0.85 and 1.15, i.e. twice that of building new freeway links in the Paris region.

VMS in Southampton

Following the initial trial of three route guidance signs from 1992 to 1995, the system was expanded to 47 signs (McDonald et al, 1996). A total of 26 route guidance VMS have been installed in the urban areas of Southampton, primarily on key inbound routes to the city centre, although a few have been located to serve exiting traffic. Operation of these VMS is the responsibility of staff based in the ROMANSE Project Office in central Southampton. An additional 17 signs have also been installed on the M27 motorway, which borders Southampton to the north. These later signs mostly provide information relating to conditions on the motorway, and relate to route conditions in the urban area, as and when required. The motorway signs are jointly controlled by the Police (based in Winchester, Hampshire) and the ROMANSE project staff. In addition, four mobile VMS are also available for use in unusual situations which can be predicted, such as roadwork or special events. Southampton and surrounding areas now have a comprehensive coverage of route guidance VMS. The information disseminated via VMS is almost all in the form of text using electromechanical reflective flip-dot matrix display technology. The text message on the urban VMS can consist of 4 rows of 12 characters, while the message on the motorway signs is only 2 rows of 12 characters.

Strategies have been developed and evaluated for potential incidents in Southampton using the RGCONTRAM traffic assignment model that incorporates driver information and response functions. Practical rules for operating the VMS in incident situations have been developed. For potential incident locations, comprehensive message sets have been agreed for initial trial on these signs in response to potential incident scenarios. The strategy steps have been pre-coded into the system so that the operator can select a strategy in a single action. When an incident occurs, messages are sent from control centre based on the strategies developed to the VMS signs concerned. When no incidents occur, a message of "NO REPORTED INCIDENTS" is displayed on VMS signs.

VMS in London

The London VMS system was inaugurated in 1994 and initially consisted of 12 signs located for inbound traffic on the major primary class "A" roads leading into Central London. There are now 30 signs in total in Greater London with some of the additional signs positioned for the benefits of outbound travellers and some in outer London. A further 67 locations have been identified as proposed future sites for VMS. (Hounsell et al, 1998, Chatterjee et al, 1999)

The London VMS system was commissioned by the Traffic Control System Unit (TCSU) as a part of their urban traffic management and control (UTMC) functions. The VMS are of the electronic matrix type and each panel has the capability of displaying a total of sixty characters (four lines by fifteen). Message texts for signs in inner London are set by the Metropolitan Police – Area Traffic Control Unit, who have direct responsibility for updating the information and ensuring that signs are displaying relevant information at each location. The highway Agency have provided guidelines for the layout and contents of VMS messages to ensure consistency in the format of messages displayed to road users.

The VMS system has an operator interface via which the signs can be monitored and messages activated. 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. There are four corner mounted amber lights which can be used to emphasise very important hazard warning messages. When no information is available, the signs remain "blank".

VMS in the Scottish highway network

The development of VMS information and guidance system in the inter-urban Scottish highway network is within the European DRIVE II project of QUO VADIS (Albert M et al, 1998). The primary object of this project is to establish how VMS are best managed to give quality information and guidance to drivers and to improve the capacity of a highway network. During the QUO VADIS field trials, traffic was only influenced in the southbound direction. The four relevant VMS sites are equipped with signs which can display 4-5 lines of arbitrary text of 15 characters per line. Each VMS site has several VMS, one for each southbound inflow link, giving 14 signs in total. All the VMS at a VMS site provide the same message on all approaches, although the wording of the legends is sometimes slightly different, depending on the fixed signing for the corresponding inflow locations.

VMS on the arterial roads connecting Osaka and Kyoto

Kurauchi and Tanaka (1995) reported the effects of a real-time information system introduced in 1994 on three arterial routes connecting Osaka and Kyoto in Japan. Before the introduction of the system, there were significant difference in recorded travel times between the roads which varied between 40 and 60 minutes. The system used automatic vehicle identification technology to collect data for predicting travel times on the three routes which were then displayed to drivers through VMS.

In the study, data were collected for a month before and a month after the implementation of the system and again some months later. The results suggested that the VMS significantly contributed to the equalisation of travel time between the three routes, and that overall, journey times had been reduced, particularly by the end of the second study period. On the two dual carriageway roads, which before VMS introduction carried 71% of the total traffic on workdays, average journey times dropped by 5% and 9 % respectively.

VMS in Aalborg

Aalborg is one of the two test sites in the DRIVE II project QUO VADIS. 14 VMS have been installed in the city of Aalborg in Denmark (Dorge et al, 1996). The VMS system is intended to enable a better distribution of the traffic across the two links connecting Aalborg and Norresundby across the inlet Limfjorden. One of the links is a bridge that connects urban roads and the other is a tunnel that is part of interurban motorway. Local traffic uses both the bridge and the tunnel. In general, there is spare capacity in the network, but with anticipated repair work on both the bridge and the tunnel in the coming years there is likely to be serious congestion. The VMS have been installed prior to key decisions points on the approach roads. Traffic control system TRAFIX has been established to monitor link flow and speeds, estimates delays and activate appropriate message sets. Two different types of information are being investigated--delay times for routes up to the bridge and tunnel and route guidance to specified destinations.

VMS on the Kent corridor

As part of the PLEIADES project (CEC DRIVE II), the reaction of road users to advance VMS information on traffic problems was tested and evaluated on routes between London and English channel ports (the Kent corridor). The network comprises the parallel A2/M2 and M20 major routes, cross links between these two routes and a section of the M25 London orbital. Eventually the corridor will be equipped with 65 VMS. Hobbs et al (1994) reported that the MCONTRM traffic assignment model has been used to calculate 140 fixed diversion plans which consider a variety of events and incident scenarios occurring at different times and optimise the distribution of traffic in the network. The appropriate strategy is selected when congestion is detected in the corridor. In future an on-line network model is to be developed. Other traffic information systems are being tested in the corridor, in particular RDS-TMC, so consistency within and between the systems is being addressed from a common operations centre. The system is being evaluated by monitoring of diversion proportions at key junctions. Batac and Fraser (1995) reported that, whilst initial results are available, this evaluation work is being continued outside the PLEIADES

VMS on the Amsterdam ring road

Four VMS were installed in 1994 on four motorway approaches to the Amsterdam ring road. The signs provide motorists with information on traffic conditions on the ring road. Van Eeden et al (1996) reported on the evaluation of the scheme through surveys just before, shortly after and six months after installation. It was found that the messages influence route choice so that traffic diverts to less busy sections. General traffic flow indicators failed however to provide conclusive evidence of the effect of queue information on total traffic flows. It was clear that traffic volumes did not increase on the surrounding urban network but the effect of speed and volume increases on the motorways was to increase environmental pollution slightly. After six months queue levels had returned to their original levels. It is suggested that evaluation of such schemes at a network level may not be feasible due to day-to-day variability etc. although local effects may be reliably evaluated using detector data and surveys. Despite the evaluation difficulties the cost-effectiveness analysis suggested that as a result of travel time reductions the VMS will pay for themselves in three years and there was general support for additional VMS.

VMS in Turin

The Turin signs have been operational since October 1996 (Chaterjee K, 1999). There are 26 VMS installed on a network controlled by the Integrated Town Control Architecture (ITCE) in Turin. The signs are used to disseminate route guidance for specific destinations. The destinations are well known zones of the city, junctions or squares, car parks, sites of general interest. Destinations have been selected for each sign to address as much of the passing traffic as possible. A maximum of six destinations are included on a sign. With these signs, key destinations are permanently displayed whereas the route guidance (by direction) varies according to the control strategy. The strategy is largely based on a real-time dynamic assignment model, operating as a central “network supervisor” which calculates the “splitting rates” (turning proportions) at junction to achieve optimum network performance. These strategies are then implemented in the ITCE.

In addition to the systems mentioned above, VMS have been applied in other locations including Bristol and Valencia. Table 2.2 presents a summary of these VMS applications including objectives, road network characteristics and details of the main features of the VMS applications.

Table 2.2 Existing major VMS systems

Application Site	Network type	No. of signs and type of road network	Type of information	VMS control strategy	Sign layout	Continuous /non-continuous
London UK (Hounsell et al, 1998; Chatterjee et al, 1999)	Urban	30 VMS in Greater London, most facing in-bound traffic on arterial routes	Incident information (advance and immediate warning)	Set manually based on information from traffic congestion log	4*15	Non-continuous
Paris France (Yim et al, 1996; Durand-Raucher et al, 1996)	Urban	150 VMS on SIRIUS motorway network to east Paris	Travel Time or congestion information (including cause of the problem if relevant), depending on traffic situation and sign location	Automatic message selection based on expert system which process data from loop detectors & Video cameras	Various including 2*18	Continuous
Southampton UK (McDonald et al, 1995)	Urban	26 VMS on arterial 17 VMS on Motorway skirting Southampton	Incident information (advance and immediate warning)	Set manually or VMS plan selected from integrated strategy library	4*12 (Arterial) 2*12 (Motorway)	Non-continuous
Turin Italy (Morello E et al, 1997)	Urban	26 VMS on network controlled by the Integrated Town Control Architecture of the Turin 5T system	Route guidance indicating advised direction to specific destinations. Plus reason for diversion when advice differs from normal	VMS control system calculates sign settings to meet target flows and turning percentages	Text panel 1*24	

(Continued)

	Application Area	No. of signs and type of road network	Type of information	VMS control strategy	Sign layout	Continuous /non-continuous
Valencia, Spain (Sanchez V et al, 1996)	Urban	32 VMS	Congestion information	Automatic message selection based on link flow/occupancy data	Text 2*12	Continuous
Kent Corridor UK (Smith S A et al, 1998)	Interurban	65	Congestion Information and route guidance	VMS plan selected from 140 fixed diversion plans	--	Continuous
Osaka and Kyoto Japan (Kurauchi H, 1995)	Interurban	65	Travel time	Automatic message selection	--	Continuous
Central Scotland (Albert M et al, 1998)	Interurban	14	Congestion Information and route guidance	Automatic message selection	Text 5*15	Continuous
Aalborg, Denmark (Mammar S et al, 1996)	Urban	14	Congestion Information and route guidance	Automatic message selection	Text 5*15	Continuous
Amsterdam, Netherlands (Kraan-M et al, 1999)	Motorway	11	Congestion Information			Continuous

2.2.3 Information disseminated via VMS

(i) Incident, delay and travel time information

In Southampton and London, VMS messages are set in response to incidents (not like those VMS which are continuously shown to drivers). When there is no information to display, the signs are either set with blank or display the message of 'NO REPORTED INCIDENT '. When an incident occurs, the VMS display the following information:

- The cause of the incident (e.g. accident, roadworks)
- The location of the incident (e.g. Redbridge Road)
- Congestion levels caused ("Short Delays", " Long Delays")

VMS in Lyon and Valencia can display the same type of incident information as those in Southampton and London. However, they are continuously shown to drivers. When in non-incident conditions, traffic status on relevant routes is displayed (e.g. "FLUID", "DENS", "CONGESTIO").

In addition to incident information, the VMS in Aalborg and Central Scotland can display quantitative congestion information in terms of time delay, e.g. '30 MINUTE DELAY'. In calculation of delay, link flow model and queuing model were used. The 'link flow model' estimates the current flow on each link, based on real-time measurements and on historic data. The 'queuing model' estimates the current queue length in each link, if any, based on link flow estimation and manual operator' input,.

In the Paris SIRIS EAST network, the VMS signs were originally used to disseminated congestion information. In1996, a modified information strategy was introduced which made it possible to disseminates both congestion and travel time information. The new information strategy combined use of congestion and travel time information, although both can not currently be displayed at the same time. The type of information displayed on a sign depends on the traffic situation and sign location:

- In free-flowing traffic conditions, signs (at any location) display 'FLUIDE' with reference to specific section of road;

- In congested traffic conditions, signs at decision points between two motorways or on motorway access roads display current travel times to the next major junction on the alternative routes. An arrow indicates if the times are increasing or decreasing. Signs on motorway sections display the distance to the queue and the queue length, unless a queue has formed at the location of the sign in which case the current travel time is displayed to the next major junction;

- In the event of an incident (e.g. accident or roadworks), signs at decision points between two motorways display congestion information (queue length and the cause, or 'FLUID') on the two routes. Signs on motorway access roads display congestion information for the motorway. Signs on motorway sections display the cause of congestion as well as the distance to the queue and the queue length. In all of these incident cases, the signs alternate between two messages to provide all the necessary information.

Other VMS system which provide quantitative travel time information include those in Bristol, the interurban highway between Osaka and Kyoto in Japan. In Bristol, the VMS disseminate comparative travel time information for bus (the ride component of Park and Ride) and car. The VMS in the interurban highway between Osaka and Kyoto display the journey times on alternative routes.

(ii) Route guidance information

In Turin, VMS are used to provide route guidance to drivers with advice for the direction to travel to reach specific destinations. The VMS in the interurban Scottish highway network and Aalborg can be operated in two modes: displaying congestion information and providing route guidance.

The VMS in Turin provides route guidance to drivers with advice for the direction to travel to each specific destinations.

The VMS in Aalborg can display both plain delay information and route guidance. In Aalborg, two routes are defined for each VMS and each of the three prefixed destinations that may be displayed on the VMS. A route file contains all links from the corresponding VMS until the corresponding destination or until the rejoining of the two alternative routes. The first route is always defined as the one going through the bridge and the second one as the route that goes through the tunnel. The VMS displaying route guidance in the interurban Scottish highway network used strategies similar to those in Aalborg.

2.2.4 VMS Control strategy

Setting signs manually by operators and automatic selection based on certain control theories are the two main modes of VMS operation used in existing VMS systems. Most of the operating systems for variable message signs work with fixed rules. Because of that, traffic-sign management is extremely inflexible. Other systems, capable of making decisions based on learned experiences, require large computer capabilities for controlling traffic process in real-time.

(i) Manual strategies

In this approach, VMS messages are set by an operator who selects strategies from a library developed in advance. This kind of VMS control are used in London (Hounsell et al, 1998), Southampton (McDonald et al, 1995), and Kent Corridor Drivers Information System (Batic et al, 1995).

The principle behind a strategic diversion system is that, in the event of an incident affecting part of the network, pre-defined diversion messages can be displayed on relevant VMS to warn drivers and, when necessary, divert them onto alternative routes. By this means spare capacity on the network can be effectively utilised. In most strategic systems, a library of diversion "plans" is prepared beforehand for use by the traffic control operators. The success or failure of this approach depends upon the care taken in identifying an optimum diversion plan for each incident situation and the number of parameters used to specify each situation. Off-line modelling has been widely used to assist in the process of identifying suitable diversion plans. Some of the more important parameters that need to be considered are:

- Location of incident;
- Severity of the incident;
- Expected duration of capacity restriction;

- Immediate and future traffic conditions on the network;
- Availability of alternative suitable routes.

When an incident occurs on a link of a network, the “best” diversion strategy has to be identified by the operators from the strategy library. Careful judgement is required on the part of the traffic control operators to make sure a selected strategy is relevant, given all the circumstances associated with the incident. Experience has shown that it is all too easy for a operator to make an incorrect selection, or to introduce a diversion when it would have been more beneficial not divert traffic and to set only tactical warning signs. It is all too easy for the additional network delays arising from a single incorrect decision to significantly exceed the (generally) smaller benefits derived from weeks or months of correct plan selections.

This method, in principle, is likely to be less efficient than one using automatic message selection where much more information can be handled on line. However, considering that the lack of research evidence on drivers’ response to information and route choice behaviour, there is a risk that automatic settings of VMS may result in inappropriate action.

(ii) Automatic message selection

Automatic message selection systems were reported in the Scotland inter-urban VMS system (Albert M et al, 1998), and the Aalborg VMS system (Mammar S, 1996). The control strategies used in the two applications are similar, and is based on a simple automatic control concept with both feedback and feed-forward terms subject to user-optimum constraints. An important feature of the control strategy is the automatic selection of appropriate VMS display combinations for any traffic situation. The aim is to achieve diversion impacts by relieving certain critical road links, thus improving overall network performance. The structure of the VMS control strategy used in the interurban Scottish highway network is shown in Figure 2.1. There are two important deviations from the classical control loop:

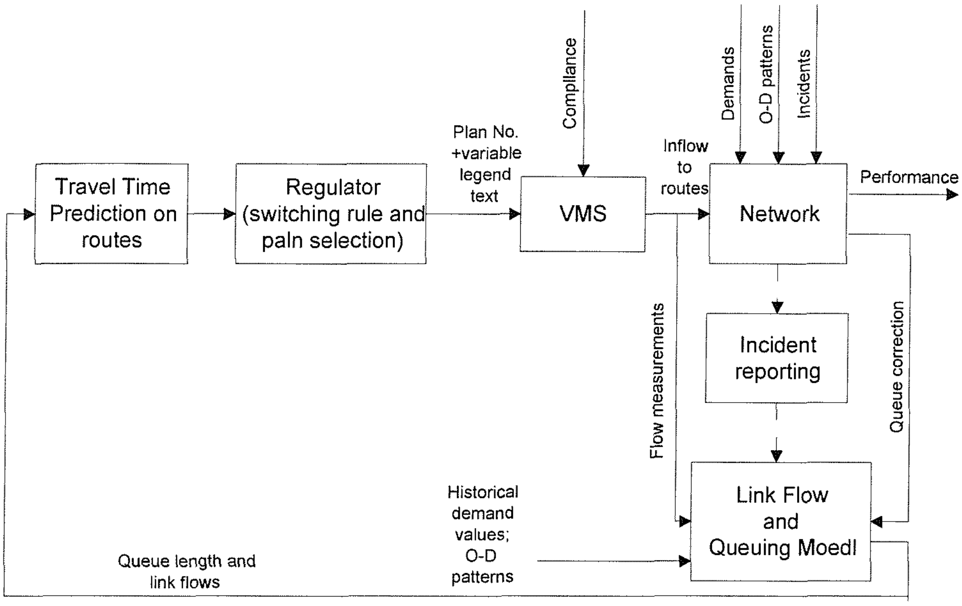

Figure 2.1 Structure of VMS Control Strategy (Mammar S, 1996)

The central part of the control strategy is the procedure which is adopted to select a plan in response to each estimated traffic situation. The steps in the plan selection procedure, which is recalculated with each update of detector information or incident reporting, are the following:

- Check the route affected by the reported incident for each VMS location and determine the predicted delay on that route due to that incident. Due to queue dynamics and the different distance from the incident location, in general a different value will be found for each VMS location.

- Estimate for each VMS location the spare capacity on the route which is not affected by the incident. The impacts of VMS on the future flows is considered in a simple way, using worst-case assumptions and the route choice simulator surveys. More precisely, each available VMS message is related to a corresponding presumed diversion splitting rate at that particular bifurcation. Although this assumption is rather crude (splitting rates may change with time-of-day, driver learning effects, etc.), it has hardly any impcat on future link flow and queue length estimations, that are using real measurements at the upstream link entries. Nevertheless, the overall control performance may be improved by employing real time splitting rate estimation.

- Decide for each VMS location on the basis of user-optimality considerations and available spare capacities whether delay information or stronger direct route advice should be displayed.

(iii) Expert system approach

The expert system OPERA, demonstrated for generating information and guidance messages on VMS in case of an incident on the Scottish inter-urban motorway network, has been designed for the QUO VADIS project (Morin et al, 1994). OPERA makes use of an on-line motorway network traffic flow simulation model for reconstruction and forecast of traffic patterns and an on-line expert system module for strategy generation.

The expert module contains the rules generating the strategies. Information messages are made up of three items: nature of the incident (QUEUE, ACCIDENT, ROADWORKS); location of the incident; description of the impacts (POSSIBLE DELAYS, 15 MIN DELAYS, DELAYS REDUCING...) or status (INCIDENT CLEARED). Guidance messages are made of four items: nature of the incident; location of the incident; a destination addressed; a recommended route or direction.

Immediately after being made aware of an incident, the expert module takes the incident into account and starts forecasting the impacts of the incident and searches for a guidance solution. VMS are identified for which there exists at least one stream of drivers complying with the following conditions:

- Its destination belongs to the main destinations defined;
- Its route passes through the incident;
- Its volume is greater than the incident;
- There exists at least one potential diversion route whose travel time is shorter than the that of incident route by more than the given thresholds (absolute or relative);
- Capacity on diversion routes are able to accommodate diverted traffic.

At the end of this step, all candidate VMS for guidance messages are identified, together with the destinations involved. Other signs display information messages. The procedure is then repeated every 6 minutes until the incident is cleared.

Additional rules allow conflicts between average messages competing for a single VMS to be solved, and check that no diversion route may be overloaded by diverted traffic from more than one VMS, and to manage to clearance phases. Instability problems are tackled by the use of thresholds and of a special procedure which, in the case of guidance being disabled on a VMS and replaced by an information message, requests the expert module to simulate the impacts and to confirm the signs if it does not entail the former diversion route becoming quicker.

The global behaviour of the expert module has been considered satisfactory by both the developers and the users, given the available data. An important issue is the validity of the driver behaviour model based on surveys made of drivers. In real conditions, drivers can adopt a choice different from that stated when they were surveyed. The other considerations underline the difficulty of finding the "optimal" strategy (i.e. minimising the overall time spent in the network). In fact, the ambition of the expert module is restricted to finding a "feasible" strategy which, in most situations, makes drivers following the guidance messages save time without entailing significant additional delays for drivers usually using the diversion route. Such strategies usually make the traffic system come closer to the individual Wardrop equilibrium (Wardrop, 1952).

2.2.5 Comment

(i) The difficulty in predicting future traffic in urban network

There are more entry and exit roads in urban road network which typically offer users a multiplicity of possible routes connecting each origin-destination pair. Also, the trip patterns in urban areas are more complex than those in peri-urban and inter-urban networks. It is difficult to provide real-time traffic information in urban network which are characterised by complex trip pattern and closely spaced junctions. Most existing urban VMS systems are used to provide information about current traffic status and incidents (recurrent and non-recurrent) which are based on traffic monitoring. VMS disseminating travel time information are mainly seen on peri-urban and inter-urban networks. The traffic patterns of Peri-urban and inter-urban networks are less complex than those in urban network which make it easier to predict future traffic on peri-urban and inter-urban network than on urban network. Research is needed to develop reliable techniques of estimating journey time in urban networks and to develop methods of presenting this via VMS.

(ii) About information disseminated via VMS

Concerning route choice, two main types of information are currently being disseminated via VMS (Table 2.3): traffic information and route guidance advice. Most of the existing VMS systems have the ability to disseminate information about current traffic conditions (e.g. events and incidents), although it is not their main mode of operation in some VMS applications. Traffic information disseminated via VMS is descriptive in nature and used to inform drivers of prevailing travel conditions. It is up to drivers to decide whether to stay on their original routes or to divert to alternative routes. The main objective of such VMS information is to help drivers in making informed route choice decisions. Traffic information disseminated via VMS can be qualitative or quantitative. VMS route guidance is provided to those drivers who pass the VMS to reach to specific destinations. However, VMS route guidance is unlike in-vehicle route guidance which provides link by link instructions to direct a driver along a prescribed path to a desired destination.

Table 2.3 Information displayed on VMS

	Continuous	Incident	Delay		Travel Time	Route Guidance
			Qualitative	Quantitative		
Aalborg	✓	✓		✓		✓
Bristol	✓				✓	
London		✓	✓			
Osaka – Kyoto	✓				✓	
Paris	✓	✓		✓	✓	
Scottish Highway	✓	✓		✓		✓
Southampton		✓	✓			
Turin	✓	✓				✓
Valencia	✓			✓		

(iii) About VMS control

Both manual and automatic selection of messages are currently being used in the operation of VMS systems. However, the fixed rules generally result in the management being inflexible. Some new approaches are being researched to improve the operation of VMS, such as expert systems, intelligent control and neural network system et al. However, most of the new approaches proposed are based on processing experience in some way. These require large computer systems with expensive software and hardware in order to perform control tasks in real time. Such methods rely on information base of decisions and effects which require considerable road detection and a continuously updated 'learning experience', although this is particularly difficult to obtain in incident situations. The lack of knowledge of driver's route choice behaviour, especially in conditions of information is another factor which makes it difficult to use expert approach to operate VMS systems.

2.3 Approaches used in assessing VMS effects

2.3.1 Introduction

Many approaches are currently being used to study the effects of VMS including preference surveys (stated preference and revealed preference), simulator experiments, network modelling and traffic measurements. In this section, the main approaches used for assessing the effects of VMS are reviewed.

2.3.2 Survey based approach

(i) Stated preference approach

A Stated Preference (SP) experiment offers decision makers a series of hypothetical scenarios to be evaluated, usually in the form of discrete choices between alternatives. The attractions of the SP approach largely stem from the ability to control the choice context and the independent variables that will enter the model (Kroes and Sheldon, 1988). This is particularly important to the analysis of the impacts of traffic information on drivers' route choice.

Durand-Raucher et al (1996) reported the evaluation work for the SIRIUS east network. A survey of 800 motorists was conducted to assess the impacts of introducing travel time messages. As an example of the results, half of respondents stated that they would divert if there was a delay of at least 15 minutes on a journey of between 20 and 45 minutes.

Wardman et al (1997) reported their SP exercise based on a trip of 34km between Warrington and Manchester City Centre (900 questionnaires handed out, with a response rate of 34%). Although drivers' response to VMS information varies according to the availability of alternative routes and the extent to which they are close substitutes, route choice could be strongly influenced by the provision of information about traffic conditions ahead. This has important implications for the use of VMS systems as part of comprehensive traffic management and control systems. Their principal findings were that the impact of VMS information depends on: the content of the message, such as the cause of delay and its extent; local circumstances, such as relative journey times in normal conditions; and drivers' characteristics, such as age, sex and previous network knowledge. The impacts of qualitative indicators, visible queues and delays were examined. It was found that not only is delay time more highly valued than normal travel time, which is to be expected, but that drivers become more sensitive to delay time as delay times increased across the range presented.

Richards et al (1999) reported on the results of a general questionnaire survey which was conducted in Southampton to assess public perception of VMS and its effects. A total of 365 commuters and 660 less frequent travellers to Southampton completed and returned questionnaires. Considering all survey respondents, 58% found the route guidance VMS either "very" or "quite" useful, and 30% claimed to have diverted on at least one occasion as a result of the signs. One of the questions asked drivers how often VMS affected their route choice. Combining all results (for all samples of commuters and infrequent travellers), 7% said often, 47% sometimes, 32% seldom and 13 % never. Of the commuters, 30% said they diverted at least once due to VMS in Southampton. The corresponding value for the less frequent travellers was 20%.

Thompson et al (1998) reported that two questionnaire surveys conducted in London at a selected VMS test site on the A1, a major principle route into London from north. Both surveys targeted commuting drivers heading towards London during the morning peak period. The first survey (Specification), conducted at the start of the year, inquired about drivers' attitudes and interpretations of VMS information. The second survey (Verification), conducted at the end of the year, was specifically designed to determine the stated diversion response to variety of hypothetical immediate warning VMS message texts. A stop-line questionnaire distribution method was employed for both surveys.
Table 2.4 indicates the stated route diversion propensity of drivers travelling into London during the morning peak, when faced with hypothetical problems on their normal route. Two problems have been identified in these two SP surveys. The first is that the stated likelihood of diverting in response to information for a journey with a purely hypothetical destination, in which the information provided was always relevant, is much greater than that for an actual real-life journey to known and /or familiar destination. The apparent over-estimation of diversion propensity highlights one of the difficulties in carrying out purely stated response experiments to determine the likely impacts of VMS. The second is that all of the response values quoted only relate to a sample of the travelling public (i.e. those who returned the questionnaire), hence the stated diversion rate may be higher than the actual diversion rate.

Table 2.4 SP responses to VMS in London (Thompson et al, 1998)

VMS information		Divert Immediately (%)	Divert Later (%)	Not Divert (%)
Non-VMS informed	Queues	19	13	68
	Queues & Delays	40	Question not asked	60
Distance to problem	Immediate	37	11	52
	Short range	38	10	52
	Medium range	25	7	68
	Long range	7	6	87
Cause of problem	Accident	30	9	61
	Congestion	17	9	74
	Roadworks	27	9	64
	Demonstration	40	6	54
What to do/expect	Delays	21	10	69
	15 min delay	20	6	74
	30 min delay	33	6	61
	Long delay	25	11	64

The CLEOPATRA project evaluated the impacts of the London Driver Information System (LDIS) through a combination of driver questionnaires, traffic monitoring and network modelling (Chatterjee et al, 1999). Most drivers in London support investment in Variable Message Signs (VMS), but current levels of diversions in response to Immediate Warning information were modest. It was estimated that Immediate Warning information can potentially produce significant benefits for drivers affected by incidents, but that there were limited overall network benefits with the existing number of signs. The survey results indicated that drivers would have diverted for about a quarter of the Immediate Warning message scenarios presented to them if they had seen the information for the journey they were undertaking at the time they received the questionnaires. However, the results of a questionnaire conducted during the activation of an actual Immediate Warning message showed that only one third of the drivers saw the information presented to them and few of these drivers diverted, although many found the information useful. The small number of diversions were confirmed by the analysis of traffic flow data. It was concluded that if the LDIS is to be utilised effectively for the management of incidents, the VMS signs need to be used more frequently, so that drivers become accustomed to seeing Immediate Warning information and become confident in the accuracy, reliability and timeliness of the information presented.

Only one quarter of an Osaka panel survey members said they had never diverted due to VMS information (Uchita et al, 1994). On the day of the survey, 19% of drivers said that they diverted from their intended route to one of the other two alternative routes with route switches being quite evenly distributed between the different routes. After 18 months of VMS operation, it was found that 40% of drivers had changed their usual route with a reduced preference for the most congested route and increased preference for the free access route. The calibration of a tactical choice model indicated a ten-minute difference in travel times is likely to result in substantial diversions.

Bonsall and Palmer (1999) reported on wide range studies from Europe and North America and showed that diversion rates depend critically on phrasing and content of VMS messages. They found that the following factors increase diversion rates: clear instructions indicating immediate action (which is not always possible or desirable); the extent of delay quoted; 'ACCIDENT' problem as opposed to 'Roadworks'; and visible congestion on intended route. The following factors decrease VMS diversion: advice without information; small quoted delay can result in fewer diversions than no information if network is usually congested; visible congestion on diversionary route; greater amount of extra time required under normal conditions to reach destination on alternative route; proportions of unfamiliar drivers if information is difficult to interpret; and previous unreliable information.

(ii) Revealed preference approach

Revealed Preference (RP) surveys have been reported in London and Southampton to study the effects of VMS on drivers' behaviour. In these sites, different methods of data collection were used. In London, the questionnaires were handed out to the drivers at stop-line locations downstream of the VMS; in Southampton, the technique of a trip diary was used.

A trip diary survey was conducted in 1998 in Southampton (Richards et al, 1999). In total, 366 respondents returned their completed trip diary packs. Based on the survey results, it was reported that the majority of respondents found the VMS legible and understandable, and between 50% and 75% found such messages useful (the percentages varies according to how 'active' the VMS are on that particular day). The percentage of drivers diverting varied between 14% and 75% depending on the situation. Considering all survey respondents, 58% found the VMS either 'very' or 'quite' useful, and 30% claimed to have diverted on at least one occasion as a result of the signs.

Drivers' revealed responses to active Variable Message Sign information in North London was surveyed during autumn 1998 as part of the Demonstration stage of the CLEOPATRA project (Firmin et al., 1999). The information displayed related to delays caused by roadworks downstream of the VMS location on the A1 Archway road in London. The information was relevant to only this one site in the London system. A survey of drivers' revealed behaviour in response to the message was conducted during off-peak conditions. The findings of this survey were reported in terms of drivers' use of the information, their revealed (reported) behaviour and their opinions of the VMS information, both specifically in relation to the sign location, and in general. The questionnaires were handed out to the drivers at stop-line locations entering the Archway gyrator system, downstream of the VMS. The questionnaire contained sections relating to driver characteristics, journey details, including a map for the drivers to indicate their main and alternative routes into London; use of traffic information sources, and a set of questions pertaining to the use, opinion and reported response to the VMS message on the day of the survey. A total of eighteen questions were included in the questionnaire and a total of 1000 questionnaires were distributed. The response rate of VMS questionnaire was 20%.

2.3.3 Simulator experiment

Route choice simulators are computer-based tools for collecting data on drivers' route choice (Ben-Akiva et al, 1991; 1997). They achieve this by requiring subjects to 'drive' through a representation of a road network while providing them with a sequence of stimuli similar to those which they would receive, were they making the journey in a real network. Thus, in the most advanced route choice simulators, the computer displays a sequence of views of the roadscape as the subjects progress down each link and provides auditory and visual cues associated with these views. An artificial dashboard depicts the speed at which they are travelling and reports on elapsed time and distance travelled. The drivers select their route by choosing their desired exit for each junction encountered and will then see the road view appropriate to that choice. The time taken to complete the journey is proportional to what it would be in real life and so will take longer if the driver selects slow or congested roads, or attempts to make difficult manoeuvres such as turning right across a street of traffic. Route choice simulators offer the experimenters a high degree of control over the network structure, the traffic conditions and the presence or absence of various forms of route guidance. They thus constitute a very powerful aid to research into the importance of each of these factors on driver' s route choice and therefore on overall network performance.

A number of route choice simulators have been developed in the last few years (Allen et al, 1991; Adler and McNally, 1994; Koutsopoulos et al 1995; Bonsall et al, 1997). These simulators differ in terms of their user interface and other features, but almost all of them have been designed primarily to explore the impact of information and guidance systems on driver route choice. They have been particularly popular in this role because of the difficulty, or in some cases impossibility, of gathering data on real-world response to new or novel technologies, some of which are not yet widespread production, notably stated preference surveys, may be criticised as failing to give the subject a realistic impression of the consequences of their responses to new systems.

Bonsall et al (1997) reported the validation of a route choice simulator known as VLADIMIR. A stated preference analysis was undertaken to compare VLADIMIR data with those from a more conventional, paper based approach. Subjects for both experiments were drawn from the same population and were presented with equivalent VMS guidance in identical O-D contexts. Route choice models were estimated from each data set and then combined with a scaling constant. The scaling constant was found to 1.5—indicating that the variance of the error in the VLADIMIR-based model was significantly greater than that in the SP-based model. Analysis revealed that this reflected the tendency of the VLADIMIR subjects to be much more sceptical about the value of the guidance and to take more factors into account when deciding which route to follow. This result was interpreted as evidence that VLADIMIR data is less affected by the 'good subject bias' which is thought to cause subjects in conventional SP exercise to behave with exaggerated rationality.

2.3.4 Modelling/simulation approach

(i) Aggregate methods

Aggregate methods are widely used to explore the effects of traffic information on network traffic efficiency. There are several models which are currently in commonly use. Examples are CONTRAM, RGCONTRAM, MCONTRAM, SATUTRN, INTEGRATION, DYNASMART, all of which have been developed independently and employ very different techniques. The main reasons of such wide recognition of aggregate methods in modelling route choice are that aggregate methods use formulas with parameters such as vehicle flow and capacity which are averaged over a period of time. Aggregate methods are less demanding than microscopic simulation models on computer power, employ relationships for queue/delay estimation which have strong theoretical or empirical basis (or at least have well tried and tested), and have the advantage for most applications of producing estimates of average travel times directly.

The use of VMS in Integrated Urban Traffic Management (IUTM) has been studied as part of the ROMANSE initiative (McDonald, & Richards, 1996). Strategies have been developed and evaluated for potential incidents in Southampton using the RGCONTRAM traffic assignment model that incorporates driver information and response functions. The strategies involve route guidance and information through VMS and in some cases adaptation of the UTC system timings in such a way as to maximise benefits from the strategy implementation. One objective of the modelling was to produce a log of strategies from which one could be selected for a given incident. The strategies were focused on the major arterial roads and were intended to be 'robust' in that they resulted in significant benefits compared to the "do nothing" scenario while accounting for the possibility of a wide variation in diversion proportions. The later was important since drivers' response to VMS was not understood well enough to predict precise diversion proportions. Off-line modelling was the most viable method of developing strategies in a controlled environment.

It is reported by WS Atkins (1995) that New Scotland Yard staff estimate that approximately 80% of messages they set are of the advance warning type (i.e. for planned events). However, there are some indications that the VMS were significantly under-utilised for unpredictable incidents. Limited network modelling applications were undertaken during the WS Atkins study to investigate possible network impacts of VMS. One application involved the use by WS Atkins of the SATURN Heathrow Road Traffic Model (HRTM) network (which included two VMS operated from Heston), to model the impacts of 8 unpredictable incidents of duration 30 min or 60 min various severity. Results indicated that:

- The optimum diversion rate to produce maximum benefits varied between 2%-62% depending particularly on incident severity and network loading (Highest diversion rates applied to severe incidents in a lightly trafficked network).

- Assuming a 10% diversion rate, journey time savings for drivers encountering VMS ranged from -0.7% to +12% (average 3.4%) for the 8 incidents. Equivalent network benefits ranged from -0.1% to +1.0% (average 0.4%).

Clearly the optimum diversion rate is situation specific, and the VMS message should reflect the severity of the incident and would therefore be expected to generate different diversion rates. The second application involved the use by TRG of the RGCONTRAM model for a 100 sq km network of inner/northern London. One VMS installation was modelled (A1, Archway Road) with 6 unpredictable incidents of duration 30 min or 60 min and moderate or high severity. Results indicated that:

- The optimum diversion rate to produce maximum benefits ranged from 0% to 30%.

- Assuming a 10% diversion rate, journey time savings for drivers encountering VMS ranged from -0.9% to +2.4% (average +0.4%) for the 6 incidents. Equivalent network benefits ranged from -0.5% to +0.3% (average -0.05%).

The lower (and sometimes negative) benefits for RGCONTRAM reflect (i) the much higher congestion in this network than in the HRTM network and (ii) the probability that the optimum diversion rate would be well below 10% in many of these cases. These modelling results, restricted to unpredictable incidents of duration < 1 hour, represent 20% of situations where VMS would be activated. Higher benefits would be expected for the longer duration incidents and substantial additional benefits may be expected if other driver responses in addition to re-assignment are included, particularly for the planned events.

(ii) Microscopic simulation

Microscopic simulation models attempt to mimic the behaviour of each vehicle as it moves through the road network, based on of the vehicle and driver characteristics (Hoogendoorn et al, 1997). The process is split into a number of sub-models or modules such as:

- defining the characteristics of the vehicle and driver behaviour;
- vehicle following module ;
- lane-changing module.

Within these modules there are separate relationships governing particular processes such as acceleration, overtaking, driver reactions, etc. The various models vary somewhat in their assumptions about vehicle and driver behaviour, but most require the input of mean values for such things as desired speed and vehicle performance. The values for individual driver and vehicle are then selected from distributions about these means. Evidence for both the mean values and the distributions is currently poor as it relates to VMS use.

Microscopic simulation has the advantage of that it offers the potential for dealing fully and realistically with all aspects of flow interaction. With the increasing power of computers, the representation of individual vehicles in microscopic simulation models, such as AIMSUN (Barceló et al, 1997), has now become a practical alternative approach to aggregate methods. However, any model must be validated before use.

2.3.5 Street observation

Haj-salem et al (1995) report on field trial results for an investigation of the effects of different message types on the performance of the Corridor Périphérique ring roads. In May to July 1994, there was a weekly alternation of travel time displays and queue length message displays for the 350 VMS of the Corridor. Traffic data was collected for the period 7am to 9pm from a large number of detectors. It was found that with travel time message rather than queue length message the total time spent on Boulevard Périphérique (BP) increased by 2.7% and on the Boulevard des Maréchaux (BM) reduced by 2%. This is explained in two ways. Short distance trip makers use or continue to use the BP when well informed of travel times. In congested conditions, less BP users divert to the BM with travel time messages since they are less uncertain about the conditions than the queue length messages. The finding was confirmed by diversion analysis at strategic nodes, which showed that the level of diversion to parallel street to be 10% less with travel time messages.

Yim and Ygnace (1996) studied a freeway access ramp in the Paris SIRIUS EAST network and quantified the relationship between changes of queue length indicated by VMS and the diversion rate of traffic to an alternative route instead of freeway. In the morning peak, a 1km queue length caused a 7% diversion rate, a 2 km queue length caused a 11% diversion rate, a 3 km queue length caused a 17% diversion rate, and a 4 km queue length caused a 31% diversion rate.

In the CLEOPATRA project, the impacts of VMS were evaluated through message demonstrations in London (Chatterjee K et al, 1999). Two incidents were selected for the demonstration phase. Both incidents were planned roadworks, where VMS were set in Immediate Warning mode at the beginning of the works. This enabled surveys and data monitoring to be planned in advance for incidents for which motorists had no advance warning. For both incidents, the message was displayed on the A1-Archway VMS, a sign in North London on a major arterial route into central London. The roadworks locations were 1.7 km and 1.5 km downstream of the VMS respectively. Traffic data were collected from 10 detectors in the vicinity of the incidents.

Dorge et al (1996) found that comparative travel time for two river crossing routes in Aalborg resulted in 22-39% diversion rates. Bovy (1998) found that the indication on VMS approaching the Amsterdam outer ring-road of 4 km queue length in the Coentunnel resulted in a 12% diversion rate of traffic to alternative route. The introduction of VMS has improved the distribution of traffic on the ring-road. When congested the amount of traffic using the Coentunnel has been reduced by 4% and when non-congested traffic has increased by 10%, resulting in an overall increase of flow of 6% despite congestion being prevalent for long periods of the day. Ramsay and Luk (1997) found that notification of an incident ahead resulted in 20% increase in freeways exit flows from at the next exit in Melbourne and Brisbane. However, there were little effects on the amount of traffic entering the freeways.

Swann et al (1995) reported on the use of traffic flow data and traffic and traffic assignment model predictions to calculate diversion rates for the Forth Estuary Driver Information and Control System (FEDICS) located on the inter-urban road network in central Scotland. They reported 1% to 9% diversion rates for the road closure information, 12% to 13% diversion rates for reports of queues on the Forth Road Bridge and a 6% diversion rate for roadworks notification. These figures represent diversion rates for drivers to whom the messages are relevant of 80% to 100%, 13% to 14% and 40% for the three respective types of information

2.3.6 Comment

Survey, simulator, modelling and street observation are the main approaches used to study driver's route choice behaviour and the effects of VMS on traffic flow. The attractions of the SP approach largely stem from its ability to control the choice context and the independent variables that will enter the models to be used. The main limitation of the stated preference approach is that people may not necessarily select routes in the way stated. The approach of revealed preference has traditionally been used to study travel behaviour based on data obtained by direct observation of traffic or obtained in surveys asking about actual travel behaviour. A comparison of the chosen travel alternatives and the rejected alternatives reveals the preferences of the travellers. By the use of appropriate statistical technique the implicit utility functions of the travellers can be inferred. The main limitation of this approach is that revealed preference surveys cannot be used in a direct way under conditions which do not yet exist. Previous studies showed that the revealed-preference responses (i.e. drivers who actually took alternative routes with traffic information) were lower than the stated-preference responses (i.e. drivers who said they would take alternative routes). Further studies are needed to verify survey results of drivers'response to VMS.

Route choice simulators offer experimenters a high degree of control over the network structure, the traffic conditions and the presence or absence of various forms of route guidance. They thus constitute a very powerful aid to research into the importance of each of these factors on driver's route choice and therefore on overall network performance. Despite many theoretical and intuitive reasons why route choice simulators might be valuable tools for exploring route choice behaviour, the central question remains as to whether the behaviour of subjects in the simulated network is indicative of what their behaviour would be in an equivalent real network. The auditory and visual environment to make route choice simulators valuable is particularly important.

Simulation/modelling is similar to the laboratory experiments conducted by physical scientists to gain insight into the existing theories or to develop and validate new theories. Typically, models are used rather than a real world system for one of three main reasons: (i) the real world system does not exist; (ii) experimentation with the real world system is expensive; (iii) experimentation with the real world system is inappropriate. The main advantages of a simulation approach are that network modelling offers a controlled environment which makes it particularly appropriate to explore the potential network effects of VMS on traffic efficiency. The main limitations of a modelling approach are: model validation is difficult; results can be easily misinterpreted and it may be difficult to trace the source of errors.

Results based on field data are valuable in representing reality, and is commonly used to validate the results from non-field data based approaches. A variety of techniques have been used by researchers to study drivers' route choice behaviour in response to VMS. However, the results from different approaches are different, and it is not possible to obtain a single clear understanding of drivers' response to VMS in real world networks. Street observation will be helpful to validate the results from variety of models suggested

2.4 Comment

(i) About current VMS applications

Traffic information/guidance systems offer considerable opportunity to improve driver's routing and network efficiency. However, numerous questions are raised concerning their relative benefits in different situations, as well as details concerning the optimum design and operation of each system. Both in-vehicle and off-vehicle guidance have advantages and disadvantages which makes them more appropriate to be used in different situations and serve for the different traffic demands.

VMS provide drivers with traffic information and/or advice using visual displays and one-way dynamic communication techniques. The responsibility falls upon drivers to understand the information and/or advice to determine what, if any, part of a message applies to their trip. VMS information could have many impacts on travel, especially in conditions of an incident, e.g. provide advance or immediate warning of adverse traffic conditions, provide route choice advice, reduce stress and increase travel safety.

(ii) About VMS control

Currently, VMS signs are set manually or automatically. Many new approaches have been tried to increase the efficiency of VMS operation, including expert systems, neural networks, and fuzzy logic. Although such new approaches have great potential in improving VMS operations, current knowledge of driver behaviour has not reached the stage to make such new systems generally practical.

(iii) Main problems of current VMS applications

Most initial evaluations and strategies of VMS systems are based on the results of survey, modelling or simulator experiments. Most transport managers and VMS operators have realised that to improve the effectiveness of VMS systems, the key issue is to understand how drivers respond to current VMS information and to know the network effects of VMS information.

Interview/questionnaire surveys, modelling and simulator experiment have been used in many research projects to study drivers' response to VMS information. Although very helpful in understanding drivers' routing behaviour, the lack of consistency between results from different approaches is a concern. Field studies based on measurements thus become very important to verify the subjective results from interview/questionnaire surveys, modelling and simulator experiments. Field results are very useful in understanding drivers' real response to VMS, and improving current modelling and simulator experiments which require knowledge of driver behaviour.

(iv) About models of route guidance

Models of route guidance have become increasingly sophisticated in recent years and most now attempt to deal with network interactions. Models combining assignment and simulation sub-model and models based on driver behaviour concept have the advantage over traditional pure assignment and pure micro-simulation methods in representing drivers response to traffic information/guidance.

3 Modelling VMS effects using RGCONTRAM

3.1 Modelling requirements

To model the effects of VMS information, the following requirements have been identified for the model to be used:

(i) Dynamic modelling of time varying demand, queuing and congestion, including junction interaction and the effects of incidents, particularly the build up of queues leading to block-back (i.e. the spread of queues up to upstream links). These being the key situations when VMS is active and potentially beneficial.

(ii) The means to model the VMS implementation(s) and information provided (e.g. location and information characteristics (type of message, duration, etc.).

(iii) The capability to represent driver's re-routing in response to VMS information provided.

(iv) The ability to model networks of sufficient size and details to represent all link/junction types and control features, including the ability to represent a sub-network.

3.2 Selection of modelling tool

3.2.1 Existing models

From described in Section 3.1, it can be seen that a model with the function to represent individual driver's response to particular condition (single day) and information is the key requirement. In this section, typical models which have the function to model driver's response to information in a 'single day' environment are reviewed:

(i) AIMSUN

AIMSUN (**A**dvanced **I**nteractive **M**icroscopic **S**imulator for **U**rban and **N**on-Urban **N**etwork), (Barcelo and Ferrer, 1997), is microscopic traffic simulator whose main features are:

- Two different types of simulation are involved: one based on input traffic flows and turning proportions, and one based on O-D matrices and route selection models. In the former, vehicles are distributed stochastically around the network, whereas in the later vehicles are assigned to specific routes from the start of their journey to their destination.

- Vehicle behaviour models (car following, lane change, gap acceptance, etc.) are function of several parameters that allow modelling of different types of vehicles: cars, buses, trucks etc. They can be classified into groups, and reserved lanes for given groups can also be taken into account.

- AIMSUN2 has a user-friendly interface through which the user can define the simulation experiment. It also provides a picture of the network and an animated representation of the vehicles in it. The user has an overview of what is happening in the network that aids performance analysis.

- Through the interface, the user may access any information in the model and define traffic incident before or during the simulation run. A list of incidents may be stored for use in subsequent simulation runs.

(ii) DRACULA

The DRACULA model (Liu, Van Vliet and Vatling, 1995) being developed at the University of Leeds which is not concerned with average travel behaviour but day-to-day behaviour. The framework consists of separate demand and supply components. The demand component consists of probability models for individual trip-making, some of which do not depend on the supply model and others such as route choice depend on the current network state and the driver's knowledge base (e.g. previous day conditions). Individuals updated perceived travel costs via some types of learning mechanism such as those considered by Ben-Akiva and colleagues (1991). The demand component provides a trip matrix including intended departure time and route for each vehicle.

The supply model is microscopic in nature with updates of the speeds and position of individual vehicles every second. The traffic dynamic approach has a higher fidelity than in PARAMICS with vehicles moving on a continuous basis (i.e. they can move to any point on a link, rather than hopping from one cell to another). The characteristics of each vehicle are specified in terms of type and driver behaviour (randomly generated values for reaction time, desired speed, deceleration rate, minimum headway). Each vehicle is processed through the network on the route from the demand model according to a car-following model, the lane-changing rules and junction controls. In-trip reassignment has not yet been included in the supply model. The developers acknowledge that DRACULA is at a formative stage but say its ability to model the network state to fine resolution make it well suited for studying issues such as traffic control systems and congestion pricing.

(iii) DYNASMART

As a precursor to DYNASMART, Mahmassani and Chen (1993) designed a simulation program to analyse driver route choice in simple networks. Equipped drivers are assumed to receive pre-trip and en-route travel information of prevailing (as opposed to forecast) journey times on competing routes. Route selection and switching was either based on 'myopic' or deterministic choice, where a driver will switch to another route if there is any gain, or boundedly rational choice, where a driver will only switch if the improvement exceeds a certain amount.

Jayakrishna et al (1994) described the simulation-assignment model DYNASMART developed for evaluating networks under dynamic travel information. It has following three components:

- Nature of traffic flow that results from driver responses and applied network control
- Response of drivers to information/control
- Dynamics of the routes in the network that affect the driver and control system decisions

Vehicle movement during each time step is based on the speed in the link resulting from the density at the end of the previous step, i.e. first-order macroscopic flow principles which incorporate congestion information and shock wave propagation. This representation of traffic flow provides a more realistic representation of congestion information than the queue formulae and blocking-back procedure of CONTRAM and its successors. The movement of individual vehicles is simulated using link pass and node pass routines. Movement at nodes depends on driver response and link outflow and inflow capacities (which take account of signal control etc.). Link travel times are calculated at the end of each time step. Incidents can be simulated in a similar way to RGCONTRAM.

(iv) INTEGRATION

INTEGRATION (Van Aerde and Yagar, 1988) which like SATURN (Van Vliet, 1982) also combines assignment and simulation techniques which has been designed to evaluate recurrent and non-recurrent congestion in urban networks. Like CONTRAM it seeks to achieve dynamic equilibrium. Traffic is loaded incrementally (a vehicle at a time) based on a time-slice O-D demand matrix. Each vehicle is initially assigned on the current least cost route (stochastic choice is permitted by including random part in costs) and not the expected future least cost route. This is a notably different approach to CONTRAM.

In the simulation the iteration of individual vehicles along links is modelled using speed-flow relationships and lane changing and car following logic. Vehicles are queued in a stack at junctions with the stack checked every one tenth of second to check the departure time of the next vehicle. Delays are recalculated every 6 seconds. The chosen route can be changed at any junction, for example if there is an incident (incident parameters can be specified by the user). Since route choice is based on current conditions, journey time predictions are not required and there is no need for iteration.

Van Berkum et al (1996) reported on applications of INTEGRATION to assess the impacts of congestion relieving schemes in the Netherlands. The described applications include ramp-metering, construction of additional freeway lanes and the environmental effects of incidents.

(v) PARAMICS

PARAMICS (PARAllel MICroscopic traffic Simulator; Mcarthur, 1994) originally developed at Edinburgh Parallel Computing Centre, is a microscopic simulator of individual vehicles based on Newton's law of motion rather than traffic as a viscous fluid. The traffic dynamic model is a cellular automata or particle hopping model. Each road lane is divided into 7.5m cells and vehicle positions are updated every second according to the number of unoccupied cells ahead. It has elements of car following and fluid dynamics traffic models, combined to enable fast computation. As well as distance-keeping heuristics, vehicles are able to change lanes in certain situations and junction controls are represented.

The PARAMICS-CM enhancement allows modelling of driver in-trip responses to information. It has been applied to modelling of VMS on arterial roads in Edinburgh. This version includes a mechanism for dynamic route determination to enable vehicle re-routing while the simulation is underway. The information network is superimposed on the traffic network and information is specified in terms of three formal data structures (events, effects and route updates). A rule language has been established for driver response to incidents and the rules being used in VMS evaluation reflect the results of CEC DRIVE project QUO VADIS (Bonsall et al, 1994) where PC-based route choice simulators were used to identify driver responses to variety of simulations. The route choice rule set covers the following vehicle types and circumstances:

- Response to observed congestion
- Response to ATT-information incident
- Response to ATT-informed incident with advised diversion
- Buses
- HGVs
- Initial routes

While the PARAMICS model exhibits many of features to be described in a modern microscopic model, it has yet to be credibly validated.

(vi) RGCONTRAM

RGCONTRAM (McDonald et al, 1995a) has been developed at the University of Southampton to model route guidance operations. The emphasis in RGCONTRAM has been on 'single-day' modelling (traffic conditions on specific day rather than a normal day) with enhanced traffic incident and driver behaviour sub-models. RGCONTRAM model enables interrelationships between system operation, network performance and driver response to be explored in a way which is not possible with a traditional equilibrium model. This is achieved by repeated model application to 'one-day' situation, to represent the typical variability that is likely in practice.

RGCONTRAM can operate in either of two modes:

- As an equilibrium assignment model, which produces a stable and user optimum solution subject to the characteristics of the dynamic route guidance (DRG) systems. Equilibrium modelling can be useful for design by producing optimal solution against which actual system performance can be judged and for studying DRG system characteristics which are less sensitive to day-by-day traffic variability (e.g. the required extent of the DRG network or the average effects of maintaining 'single route' algorithms as DRG penetration increases).

- As a 'once-through' non-equilibrium simulation, to study DRG and network performance for specific scenarios (e.g. during an incident) where the dynamic processes dominate and preclude the use of an equilibrium approach.

(vii) MCONTRM

MCONTRM (TRL, 1994) is a CONTRAM-based model which has been designed to model driver responses to ATT systems. MCONTRM can be used to develop practical VMS strategies and to produce recommendations for operators. The user can specify that motorists passing VMS either use fixed diversion routes or allow free re-routing at the VMS; the proportion of traffic diverting; and the timing of the display relative to the incident. A VMS strategy can be selected from comparison of three scenarios: no VMS information; all traffic has complete knowledge (user optimum); traffic which passes VMS has complete knowledge. A weakness of MCONTRM is that the user makes assumptions regarding driver response and may have to carry out sensitivity tests.

(viii) ROGUS

ROGUS (Harris et al, 1992) was the first variant of CONTRAM (Leonard et al, 1989) to model dynamic guidance. The assignment of unguided drivers was based on stochastic (randomly perturbed) minimum cost routes. The sub-model for assigning guided drivers included simulation of the operation of roadside communication beacons and an event-based simulation. Standard CONTRAM delay and queue calculations were retained. Link costs for the guided drivers were based on a combination of historical data (from a previous model run) and real-time data. The purpose of ROGUS is to enable the investigation of control strategies applicable to the guidance of vehicles, which receive routing instructions from beacons placed at the road side.

The main parameters which are user specified include the percentage of guided vehicles, the amount of distortion applied to the travel cost of vehicles to provide sub-optimal routes, the number and layout of roadside beacons, frequency of guidance information update, the weight given to different sources of estimates of link journey time, the biasing of route selection in favour of those which pass through a beacon, and the transmission delays associated with receiving information from guided vehicles and traffic sensors.

The main uncertainty of the ROGUS model is the significant difference in the assignment method of guided and unguided traffic and how both groups interact with each other. The user has the option of either allowing the assignment of unguided traffic first, followed by the assignment of guided traffic, or vice versa.

3.2.2 Comparison of the models

The main features of above models are summarised in Table 3.1. The models are classified according to be following 7 attributes that are corresponding to a breakdown of the model requirements described in 3.1:

(i) Model type: Traffic flow characteristics can be represented in three levels – microscopic, mesoscopic, and macroscopic. At the microscopic level, traffic is modelled by treating each vehicle as a single entity. This level of representation is important in modelling detailed vehicle dynamics such as car-following, lane-changing, or weaving behaviour. At the macroscopic level, on the other hand, traffic is modelled as a stream of flow. Gross performance measures such as link speed and travel time are the ultimate objectives of this level of representation. Without capturing detailed vehicle dynamics, macroscopic models relate vehicle volume or density measures directly to link speed or travel time. Mesoscopic approaches are a middle ground between microscopic and macroscopic models. They use macroscopic models to derive the travel time of the "flow" part of vehicle travel, and microscopic representation to "move" individual vehicles consistent with the "flow" part travel times, queuing conditions, and origin-destination requirements. They can capture the properties of continuity (e.g. smooth traffic) and discontinuity (e.g. shocks) in traffic flow.

(ii) Route choice: this relates to whether route choice is dynamic, implying that a model has the ability to provide different routes for different driver groups within modelled period, or static, where the same choice of routes are made regardless of departure time.

(iii) Variability: This relates to day-to-day, single-day, and long-term variability in traffic conditions. Advanced Transport Telematics (ATT) systems are designed to influence traveller's behaviours in congested network conditions by providing relevant information before and after they set off. The ability to model driver's decisions within a specific day (single day) is one of the key requirements for ATT models. However, as traveller's decision on a particular day might also be affected by experience from previous days, so it is important to model the day-to-day effects of information. In addition, ATT systems might contribute to long term changes in traveller's attitudes to information, strategies adopted and even life-style.

(iv) En-route Information: This relates to the ability to model the provision of traffic information to influence route choice. The attributes of traffic information that may be used to influence route choice, including time scale: instantaneous or predictive; instructional type: descriptive or prescriptive.

(v) Incident Management: This relates to the ability to model unpredictable incidents. Three attributes are needed for this modelling: incident location, incident occurrence time and duration, and incident severity in terms of capacity reduction.

(vi) Queue Block-back: This relates to the ability of the model to represent the build up and movement of vehicles along a link and the possible blocking-back to upstream junctions. Three main types of queue representations are used in models: (1) vertical queuing where all queuing vehicles are held at the stop-line, hence, blocking-back is not represented; (2) diagonal queuing which use vertical queuing, but approximately represents blocking-back by reference to a link's storage capability and flow; (3) horizontal queuing, where vehicles are moved on a link usually in fractions of a second, and consequently queuing along the link, with blocking-back is appropriately represented when is occurs.

(vii) Driver Behaviour: This relates to the ability to model drivers' route choice behaviour. Two main types of routing behaviour representations are used in models: (1) user specified compliance rate where certain levels of diversions are assumed; (2) bounded rational choice which is based on the empirical evidence that drivers are assumed to have loyalty to their current route choice and only make a switch to an alternative if there is at least a given threshold percentage saving in travel cost.

Table 3.1 Features of dynamic route choice models

	Model Type	Route Choice	Variability	En-route Information	Incident Management	Queue Block-back	Driver Behaviour
AIMSUN	Microscopic	Dynamic		Yes	Yes	Horizontal	
DRACULA	Microscopic	Dynamic	Day-to-day	Yes	Yes	Horizontal	
DYNASMART	Mesoscopic	Dynamic	Day-to-day	Yes	Yes	Diagonal	Boundedly-rational
INTEGRATION	Mesoscopic	Dynamic	Single-day	Yes	Yes	Diagonal	% compliance to routing instruction
PARAMICS	Microscopic	Dynamic		Yes	Yes	Horizontal	
RGCONTRAM	Mesoscopic	Dynamic	Single-day	Yes	Yes	Diagonal	% compliance to routing instruction
MCONTRM	Mesoscopic	Dynamic	Single-day	Yes	Yes	Diagonal	% compliance to routing instruction
ROGUS	Mesoscopic	Dynamic	Single-day	Yes	Yes	Diagonal	% compliance to routing instruction

AIMSUN and PARAMICS are examples of typical microscopic simulation models. Microscopic models have great potential for modelling fully and realistically with all aspects of flow interaction which is very important for study driver's routing behaviours. Microscopic models simulate network traffic at a very detailed level such as modelling the movement of individual vehicles along a link using car following, lane changing, and gap acceptance strategies etc. Appropriately validated microscopic simulation models are to represent the queuing process within a link and its effect at intersections, where the queue of vehicles can spill back to upstream links. However, this level of detail is achieved at the expense of a proper route choice model. In such models, the route of each vehicle passing through the network, or the fixed cost of links are given as part of the input data, and changes in route choice caused by changing travel conditions are not modelled. Furthermore the input data, memory requirement, and processing time are usually quite considerable, hence limiting the models for use on small networks or particular sections of network.

DYNASMART, INTEGRATION MCONTRM, ROGUS and RGCONTRAM are aggregate approach based models which combines assignment and some simulation/behaviour sub-models. In this approach, a single-day model can be constructed in two steps. First, an equilibrium model is used to generate a representative of base traffic pattern, possibly with some distortions of perceived costs or other values. Secondly, a sequential simulation explores the response of individual travellers (or a group of travellers) to particular conditions and information, and feeds back their impacts into the aggregate picture of the network state. This type of model avoids the need for detailed behavioural description of everyday traffic, so that most of the design and computational effort can be concentrated on the primary question which is the response of the traffic to specific change in network conditions or information provision.

Another approach to single-day model, such as specified by Ben-Akiva and colleagues (Ben-Akiva et al, 1991) and used in DRACULA (Liu, Van Vliet and Watling, 1995) and DYNASMART (Hu and Mahmassani, 1994, 1996), builds up a pattern of behaviour over a series of many days. While such an approach is potentially capable of great detail and sensitivity, it is computationally very demanding, being all-embracing may not interface well with other modules, and may be difficult to calibrate to the current state.

3.2.3 Summary

Although models based on microscopic and aggregate approaches can all model driver's route choice decisions on particular day, further research is needed to ensure the behavioural relationships and parameters adopted have the necessary theoretical and/or empirical base for the applications. The aggregate approaches to modelling all have limitations of one kind or another in their representation of flow interaction on congested networks. However, they are less demanding than microscopic simulation models on computer power, employ relationships for queue/delay estimation which have a strong theoretical or empirical basis (or at least have been well tried and tested), and have the advantages for most applications of producing estimates of average travel times directly.

It can be seen by comparing DYNASMART, INTEGTRATION, MCONTRM, ROGUS and RGCONTRAM models that different models have different strengths and weaknesses, which make them more or less useful appropriate for different purposes. As RGCONTRAM have been developed and used in Southampton for many years, and the network and demand files have been well established and used, a 'single-day' version of the RGCONTRAM which has been selected as the modelling tool for this research.

The emphasis in RGCONTRAM has been on 'single-day' modelling with enhanced traffic incident and driver behaviour sub-models. This is particularly important for modelling VMS effects. In outline, the model takes, as input, loading routes output from an equilibrium run of RGCONTRAM for the appropriate scenario (traffic level, DRG penetration, etc.). Modelling then proceeds for the specific scenario of interest and drivers are able to divert from their loading (normal) route at any junction according to predefined logic. The main features of RGCONTRAM model are discussed in more details in the following sections.

3.3 Features of RGCONTRAM important to this application

3.3.1 Generating an equilibrium route result

The first step of RGCONTRAM modelling is to carry out an equilibrium run of RGCONTRAM in order to provide base conditions (no incident and no VMS) and to generate normal routes for each packet (group of vehicles). Modelling then proceeds for the specific scenario of interest and drivers are able to divert from their loading (normal) route at any junction according to pre-defined logic.

The principle used for generating normal route results is the same as that for CONTRAM which predicts flows, queues and routes of vehicles as they travel through a network of roads. It models the growth and decay of congestion through time under temporary oversaturated conditions such as occur during peak periods. Vehicles are normally assigned to their minimum journey time route through the network.

The minimum journey time routes take into account the junction delays encountered. Three classes of vehicle can be represented and these are usually specified as cars, buses and lorries. A full range of junction types can be modelled including signal controlled, major/minor junctions and roundabouts. Allowance is made for 'Blocking-back' effects which occur when the queue fills the link and restricts traffic entering from the upstream junction.

Time variation is modelled by subdividing the period being analysed into a series of consecutive time intervals. The flows and queues on each link, calculated for each time interval, are carried over in a consistent manner from one time interval to the next. The traffic demand on the network is defined in terms of a time-varying set of flows, one for each time interval, for each origin-destination (O-D) movement. Each O-D movement is treated in groups called 'packets', with each packet being assigned independently to a route through the network.

The model uses an iterative procedure for assigning packets to take account of the congestion delay generated by other vehicles until convergence is satisfactory.

3.3.2 Familiar/unfamiliar drivers

Familiar drivers include regular users of the network, commuters. These are the drivers that are more likely to readily discern changes in traffic conditions and react to them. Unfamiliar drivers include those from outside the network who travel into the network only occasionally. Such drivers are assumed to stay on their usual routes regardless of changes in traffic conditions. Their routes are usually determined from a map and are usually main roads.

3.3.3 Incident drivers and non-incident drivers

In VMS scenarios, drivers are categorised into incident drivers and non-incident drivers. Incident drivers are those drivers whose normal routes pass through the incident link. Non-incident drivers are those drivers whose normal routes do not pass through the incident link. There are the following options for incident drivers in the VMS scenarios:

- Pass VMS and divert;
- Pass VMS, but do not divert;
- Do not pass VMS and do not divert;
- Do not pass VMS, but divert.

3.3.4 Incident specification

The key dynamic effects present in traffic are those induced by time-dependent variations in demand and capacity, the latter being particularly related to traffic incidents. The representation of traffic incidents within RGCONTRAM is achieved by reducing the saturation flow or capacity on the link(s) concerned, according to incident severity, for an appropriate number of time intervals to reflect incident duration. "Cruise speed" may also be reduced on the incident link(s) (e.g. if vehicles slow down to negotiate roadworks) and the "storage capacity" of the link can also be reduced. This parameter determines when a link becomes full (i.e. queue length equals storage capacity), affecting upstream junction capacity. Link storage reduces according to the location of the incident and the roadspace lost to traffic because of the incident.

In RGCONTRAM, the incident specification within the incident module is described by its:

- Location;
- Severity;
- Duration.

Incident location is introduced by the link number. Incident duration is modelled by selecting the start and end time interval which gives the required duration. Incident severity involves the reduction of the saturation flow by the required percentage for the time interval chosen. For example, suppose the simulation period is divided into five time intervals of 15 minutes for each. The saturation flow per time interval is 2000 veh/h. An incident occurring on link 6323 with 30 minutes duration starting from the 2nd time interval and 50% severity is specified as (Figure 3.1):

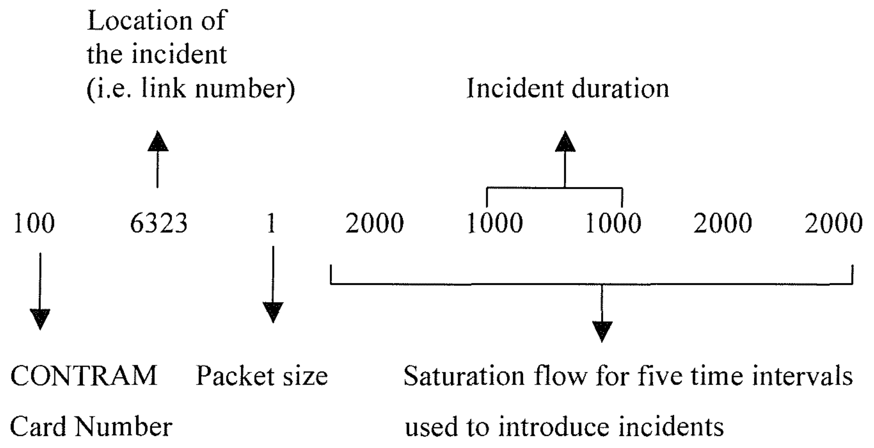

Figure 3.1 Incident specification in RGCONTRAM

3.3.5 VMS information and diversion

In RGCONTRAM, the introduction of VMS information is specified by the location and duration using the Card 94 in the control file. The diversion rate is a user-defined variable which ranges from 0% to 100%. By using this function, the effects of VMS in conditions of varying diversion levels can be investigated. For the modelling work described in this research, the following assumptions were used:

(i) In the base incident scenario (i.e. no VMS in operation), there are no diversions, all drivers use their normal route;

(ii) Drivers are divided into two categories: familiar and unfamiliar. The level of unfamiliar drivers has been fixed at 20%;

(iii) In the VMS scenario, the drivers who are diverted are randomly selected from those familiar drivers passing through VMS signs and whose original route would have passed through the site of the incident;

(iv) The proportion of drivers which divert at the VMS is user-defined. Drivers divert to user-defined diversion routes. The actual route chosen depends upon the destination of the diverted drivers;

(v) Once the diverted drivers have reached the end of their user-specified route, they reassign to their destinations using an imperfect knowledge of the current network conditions;

(vi) The drivers who pass the VMS and do not divert remain on their normal routes as in the base incident scenario;

(vii) When more than one VMS is used, the same proportion of drivers divert at each sign.

The assumption that in the base incident scenario (i.e. no VMS in operation) there are no diversions, all drivers use their normal route is true when no queus stretching back to decision points. However, some drivers might divert when such queues stretch back to the decision point. Therefore, the modelling results of VMS benefits might be overestimated by the extent to which some drivers divert because of observed congestion.

3.4 Design of modelling procedure

3.4.1 Network description

In this research, the modelling was based on the Southampton network. Southampton covers 5,200 hectares with a population of some 207,000 residents and serving a hinterland of 0.5 million. As a port city, access to the centre is constrained by the Rivers Itchen and Test (Figure 3.2), which converge on Southampton Water. It can be seen from Figure 3.2 that the network is mainly radial in nature, with a motorway (M27) skirting the northern edge of the city. A short stretch of motorway (M271) links the M27 with the western area of the city, including the western dock of Southampton. The main road connecting Central Southampton with surrounding areas include: the A33 (motorway M3, Chandlers Ford area), the A35 (Totton and Waterside areas), the A335 (Eastleigh and junction 5 of the M27), the A3024 (Hedge End and junction 7/8 of the M27), the A3025 (Netley), and A3057 (Romsey).

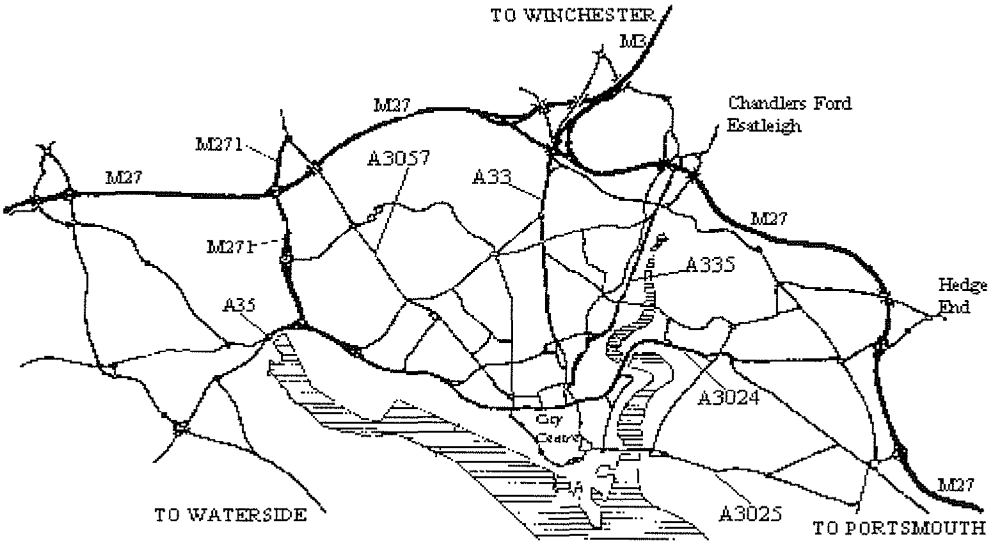

Figure 3.2 Southampton Network

The Southampton CONTRAM network was established during the ROMANSE project (McDonald, 1995). The main features of the Southampton CONTRAM network are shown in Table 3.2. It consists of 2484 links (525 signalised, 545 give-away, 1414 uncontrolled), 780 nodes (including 114 signal controlled junction, 48 round about, and other junctions). The total link length is 793 km for the whole network.

Table 3.2 Main features of Southampton network

Links			Nodes	Link length
Signal	Give-away	Uncontrolled		
525	545	1414	780	793 km

3.4.2 Traffic demand

The traffic demand for each origin-destination movement in a network is specified as a series of flow rates (veh/h) for each time interval. The pattern of demand for a particular O-D movement normally varies with time throughout a simulation period. This variation is approximated by a histogram, and the data entry takes the form of a time varying flow matrix for each O-D movement.

The demand used in this modelling are based on the CONTRAM demand files which were established in 1992 (AM peak) and 1996 (PM peak). The AM peak demand covers the time period from 07:00 to 10:30 with 10 time slices, and the PM peak demand from 16:00 to 19:30 with 13 time slices. Most time slices use a 15 minute time interval, with the first and last time slices of 30 minutes or 60 minutes (Table 3.3).

Table 3.3 Time slices for AM and PM peak traffic demands

AM Peak Demand	PM peak demand
07:00-07:30	16:00-16:15
07:30-07:45	16:15-16:30
07:45-08:00	16:30-16:45
08:00-08:15	16:45-17:00
08:15-08:30	17:00-17:15
08:30-08:45	17:15-17:30
08:45-09:00	17:30-17:45
09:00-09:15	17:45-18:00
09:15-09:30	18:00-18:15
09:30-01:30	18:15-18:30
	18:30-18:45
	18:45-19:00
	19:00-19:30

Before the modelling work, the matrix was updated to represent the change in demand. The approach of matrix updating was based on the observed link traffic flows and the CONTRAM assignment model as shown in Figure 3.3.

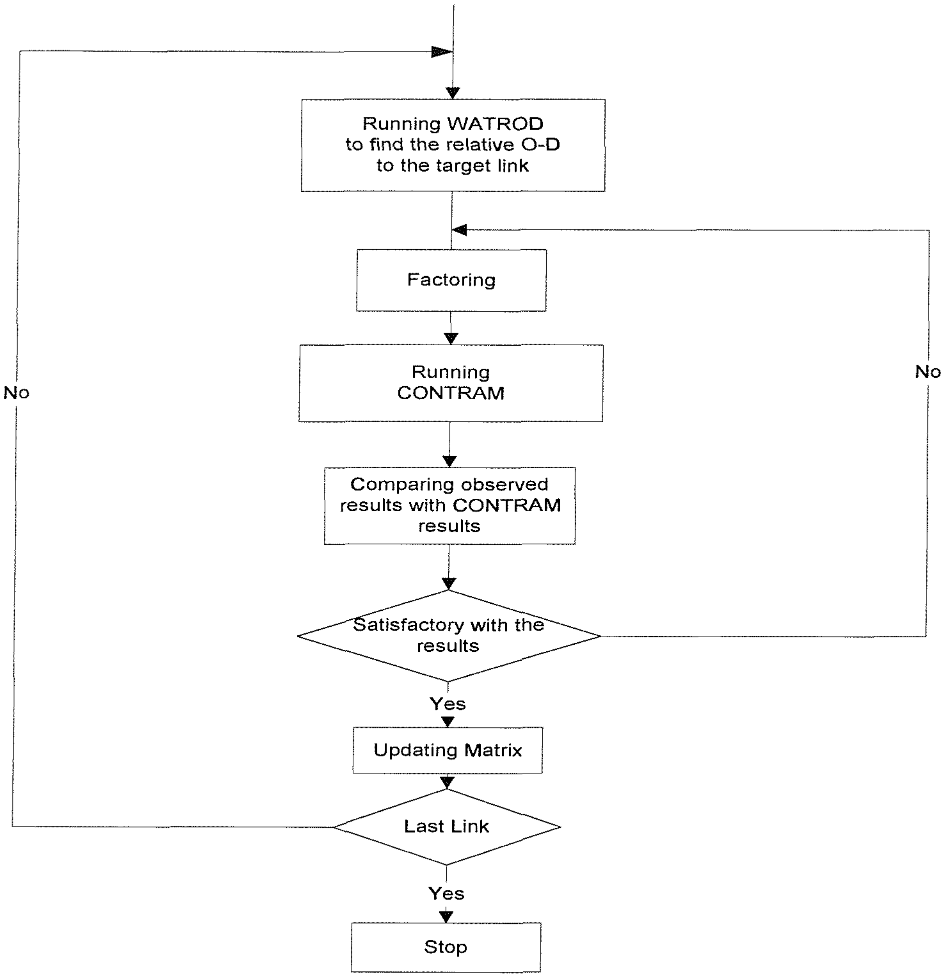

Figure 3.3 O-D Matrix prediction

3.4.3 Traffic scenarios modelled

The philosophy behind this RGCONTRAM modelling is to get deeper into the dynamics of the interrelations between system operation, network performance and driver response and to obtain a truer picture of VMS operation and benefits/disbenefits than is possible with equilibrium modelling. This is achieved by repeat model application to "single-day" situations, to represent the typical variations likely to be found in practice. VMS effects related to a number of contributory factors such as network conditions, demand, incident and VMS operation strategies. In this modelling, the effects of VMS in following traffic scenarios were investigated:

(i) Incidents

Traffic congestion and delays caused by an incident are highly dependent on the location, severity and duration of the incident. In this modelling, the effects of VMS in conditions of different incidents were investigated, including:

- VMS effects in conditions of different incident severity;
- VMS effects in conditions of different incident duration.

(ii) Traffic demand levels

Traffic demand determines arriving rates which have significant impacts on the number of drivers affected by incidents. In this modelling, the effects of VMS in conditions of different demands were investigated.

(iii) VMS duration

VMS duration is one of the key factors which determine the number of drivers who receive dynamic traffic information via VMS. There are many choices for operators to make decisions on VMS duration:

- Coinciding VMS with the corresponding incident in start and end time;
- Starting VMS behind the corresponding incident;
- Ending VMS before or after the corresponding incident.

In this research, the effects of VMS in conditions of different VMS duration were investigated.

3.4.4 Modelling procedure

The inputs for running RGCONTRAM include:

- **Network file**, which defines the physical properties of a network such as origin, destination, junctions, links and their interconnection.

- **Demand file**, which defines the time-varying traffic demand on the network.

- **Control file**, which defines the manner in which RGCONTRAM is run (i.e. the number of iterations, types of outputs to produce, VMS location, VMS duration, diversion routes etc.)

The modelling procedure using the Single-day version of RGCONTRAM is shown in Figure 3.4. The modelling procedure can be divided into the following three main steps:

The first step is to run the equilibrium version of RGCONTRAM in order to provide base conditions (no incident and no VMS) and to generate normal routes for each packet (group of vehicles).

The second step is to run RGCONTRAM under conditions of incident only. The results of this run are compared with those from the third step to assess the effects of VMS strategies.

The third step is to run RGCONTRAM under conditions of both incident and VMS. Each driver follows his/her normal routes unless an alternative exit/route is prescribed/preferred due to the effects of incident or the information provided by VMS.

The O-D matrix uses a packet 1 to generate individual vehicle modelling and allows vehicles to be labelled according to any required characteristic. In the case of VMS, labelling distinguishes drivers who are familiar with the network from those who are not, with different route choice criteria being specified for the two categories.

The outputs of RGCONTRAM include the usual CONTRAM outputs, i.e. the result file (.RES), post-analysis file (..PAF), and route file (.RTE). In addition to the usual CONTRAM summary outputs (travel time, speed and distance travelled et al), a new congestion parameter has been introduced and is used to provide another representation of the effects of an incident. The congestion index is defined as the travel time on a link divided by the cruise time. Thus, if there is no delay on a link, the congestion index will take its minimum value of 1.0. The congestion indexes on each link can then be aggregated to give a performance measure for the whole network. In the result file, the main performance indicators concerning VMS include:

- The free-moving, queuing, delay time of incident and non-incident drivers in each time slices.

- The travel speed of incident and non-incident drivers in each time slices.
- The travel distance of incident and non-incident drivers in each time slices.
- The number of drivers passing both VMS and incident link
- The number of drivers passing VMS but not the incident link.
- The number of drivers passing the incident link but not VMS.
- The number of drivers passing neither VMS nor incident link.

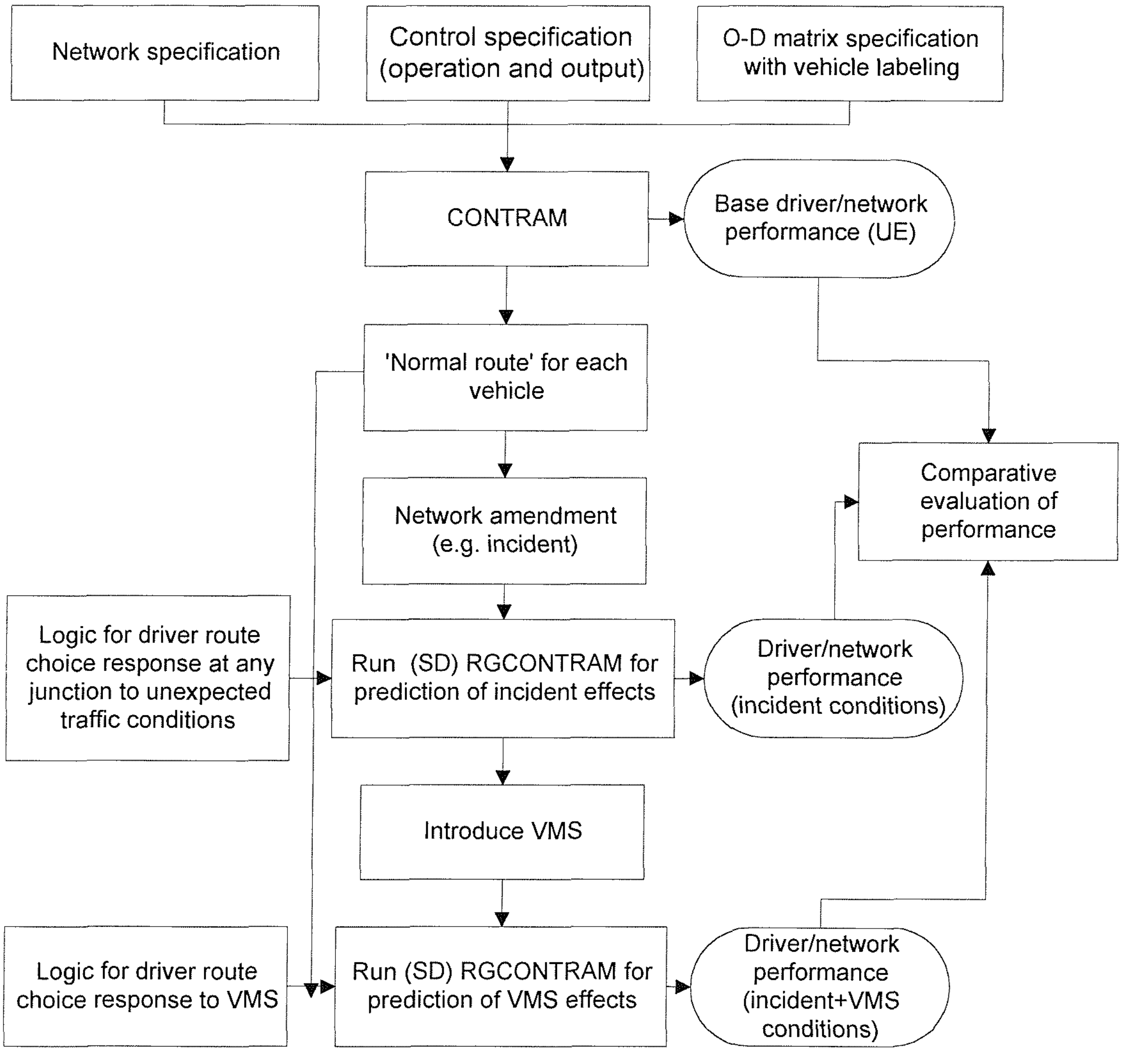

Figure 3.4 VMS modelling process for traffic incident using RGCONTRM

4 Analysis and interpretations of the modelling results

4.1 Introduction

In this section, the routing effects of VMS under different traffic/incident conditions were explored by network modelling. The major factors investigated included diversion levels, demand, incident severity, incident duration, VMS starting time and VMS ending time.

4.2 Site descriptions

The scenarios considered in this research involved an incident location on Redbridge Causeway (Figure 4.1) which is on the western approach to Southampton. This is a dual carriageway corridor with two lanes normally open in each direction. In the base scenario, the capacity of the incident link is 4000 veh/h. The incident was assumed to occur on the eastbound direction. The scenarios were modelled with three VMS signs and one diversionary route which are shown in Table 4.1:

Table 4.1 Incident, VMS and Diversion Route

Incident location	Redbridge Causeway (eastbound)
VMS Locations	H01 (Marchwood Bypass) H02 (Hunters Hill) H03 (Ringwood Road)
Diversion Route	A326 (northbound) --- M27 (Junction 2) --- M27 (eastbound)

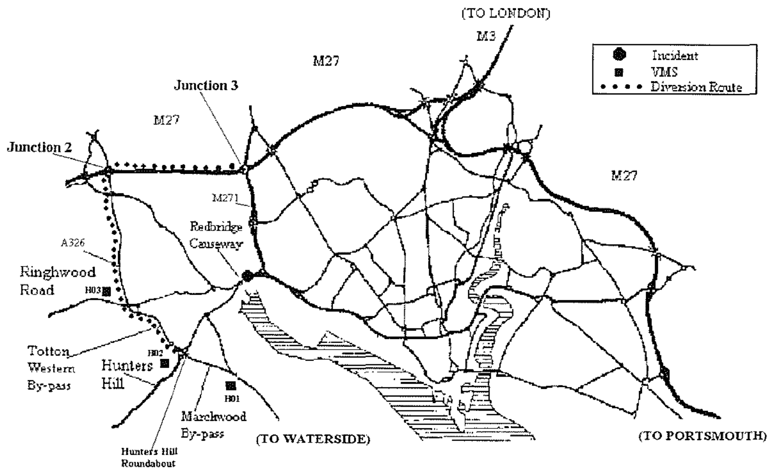

Figure 4.1 Incident and VMS locations

4.3 The effects of VMS in conditions of varying diversion levels

An incident scenario with one lane being blocked on Redbridge Causeway eastbound was modelled to consider the impacts of diversion levels. Six diversion levels from 0% to 100% were used. The display of VMS message was assumed to coincide exactly with the incident duration (i.e. the VMS are activated during the time period 08:00-09:00). The VMS benefits to each driver group in terms of journey time-savings are illustrated in Figure 4.2.

For the given network, a maximum of 1378 vehicles (Table 4.2) would pass the VMS locations and potentially divert to reach to their destinations. As shown in Figure 4.2, the incident drivers benefit from diversion, including those incident drivers who do not divert because of the reduced congestion on the incident route. In general, for this scenario, the journey time-savings of incident drivers increase as diversion levels increased. However, non-incident drivers disbenefit from diversion, especially those travelling on the diversion route. The network benefits are dependent on whether or not the benefits to incident drivers outweigh the disbenefits to non-incident drivers. For this scenario, the network drivers benefit when less than 80% of incident drivers divert. The maximum network benefits are reached when about 40% drivers divert, with a Network Percentage Recovery (NPR) of 16% (i.e. the percentage of journey time recovered from the total additional journey time caused by the incident). As can be seen that when over 60% of drivers divert, the network benefits decrease significantly, until 80% of drivers divert, when there are no network benefits from the VMS.

The results in Figure 4.2 show that an optimum diversion level exists at which the maximum network benefits can be achieved. In reality, the actual diversion levels achieved could be affected by many factors which include the messages displayed (e.g. delay/journey time information; qualitative/quantitative information), drivers' credibility to VMS information, drivers' knowledge of the network, drivers' travel objectives and travel time. Knowing the gap between the optimum and the actual diversion level will be useful for improving VMS strategies in practice.

Table 4.2 The number of diverting drivers

Diversion Levels	0%	20%	40%	60%	80%	100%
Number of Drivers Diverted (veh)	0	276	541	815	1094	1378
Network Journey Time-savings (veh-h)	0	115.2	167	159.4	31	-221.9
Network Percentage Recovery (NPR) (%)	0	11	16	15	3	-21

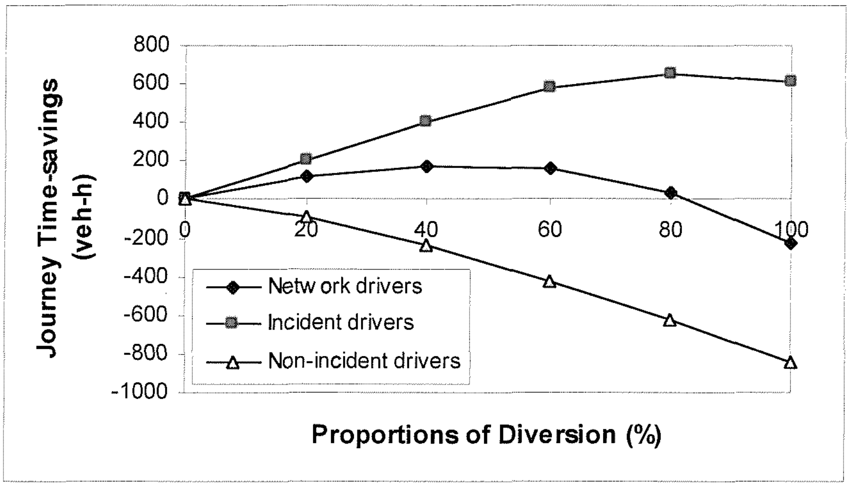

Figure 4.2 VMS benefits in conditions of vary diversion levels

4.4 The effects of VMS in conditions of varying traffic demands

For an incident which leaves one lane open on Redbridge Causeway eastbound during the AM peak period from 08:00 to 09:00, the routing effects of VMS in conditions of varying traffic demands were investigated by running the RGCONTRAM model. Five demand levels of 60%, 90%, 100%, 110% and 140% were used to consider the impact of traffic change. Of the five demand levels, 100% demand was taken as the base level which represents the traffic demand in 1998.

As shown in Figure 4.3, in the "do nothing" scenarios, the queues on the incident route increase as demand increases, whilst the spare capacity on the diversion route decreases, resulting in a network journey time increase (Table 4.3). When at 60% demand level, for example, the queue length on the incident route is 237 vehicles, the average link volume/capacity (v/c) on the diversion route is 0.36 and additional journey time caused by the incident is 174 vehicle-hours. However, at the 140% demand level, the corresponding values increased to 410 vehicles, 0.76 and 1562 vehicle-hour respectively.

Table 4.3 Queue and capacity affected by the varying demands

Traffic Demand Level	Incident , no VMS		
	Increase in Total Journey Time Caused By Incident (veh-h)	Average Queues on Incident Route (veh)	Average/Maximum V/C on Diversion Route
60%	174 (1.7%)	237	0.36 (0.78)
90%	885 (5.9%)	343	0.49 (0.96)
100%	1057 (6.4%)	354	0.52 (0.98)
110%	1226 (6.6%)	376	0.54 (0.98)
140%	1562 (2.2%)	410	0.76 (1.00)

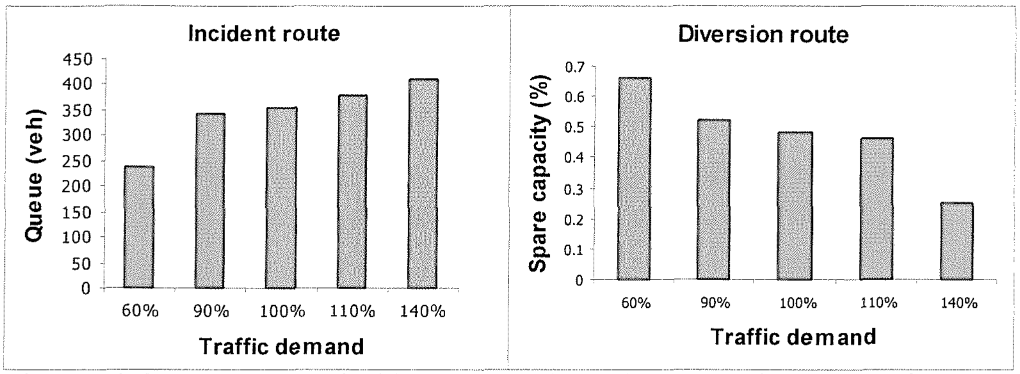

Figure 4.3 Queue length on incident route and remaining capacity on diversion route

The journey time-savings of the network drivers, incident drivers and non-incident drivers at different demand levels are illustrated in Figure 4.4, Figure 4.5 and Figure 4.6. (Note that 100% diversion at the VMS dose not mean that all traffic has been diverted away from the incident route). The unfamiliar drivers and those drivers not passing the VMS still continue past the incident location if this lies on their original route. It can be seen from the results shown in Figure 4.4 that the network benefits of VMS decrease as overall traffic demand increases. At 60% demand, the maximum network journey time-savings are reached when 60% drivers divert. As traffic demand increases, such optimum diversion level decreases. Of the five demand levels studied, the maximum network journey time-savings are reached at a 90% demand level when 60% of drivers divert.

Table 4.4 Results in VMS scenarios

Traffic Demand Level	Incident with VMS in operation		
	Maximum Network Benefits (veh-h)	Optimum Proportion of Diversion	Network Percentage Recovery (NPR) (%)
60%	125	60%	71.8
90%	250	60%	28.2
100%	167	40%	15.8
110%	144	20%	11.7
140%	133	20%	8.5

At the 60% demand level, the maximum network journey time-savings of 125 vehicle-hour are achieved (Table 4.4). This saving represents a Network Percentage of Recovery (NPR) of 72% to the additional journey time caused by the incident. This is the highest for the five demand levels considered, and as demand increases, this NPR value decreases.

The results in Figure 4.5 show that incident drivers benefit from diversion. The journey time-savings of the incident drivers increase as traffic demand increases except at high diversion levels (e.g. diversion levels > 70%). However, the non-incident drivers disbenefit from diversion and their journey times increase as demand and diversion levels increase as shown in Figure 4.6.

It may be seen from Figure 4.4 that, of the five demand levels, the maximum network benefits are achieved at 90% demand (neither very low demand nor very high demand). At low demand, there is more spare capacity on the alternative route, but less queues on the incident route due to the low arriving rate. Although diversion causes little disbenefits to the non-incident drivers at low demand, not much journey time-savings result from the VMS because of the low level of congestion on the incident route. For example, at 60% demand, the maximum journey time-savings of network drivers are 125 vehicle-hours (nearly all of them coming from the journey time savings of the incident drivers), compared to 250 vehicle-hours at 90% demand. At high levels of demand, the traffic network becomes more congested, and little spare capacity remains on the diversion route. For example, the V/C ratio on the most congested link on the diversion route increases from 0.78 (60% demand) to 1.00 (140% demand). This means that the traffic has become heavily congested on the diversion route even without diversion when at 140% demand. As shown in Figure 4.4 that the journey time-savings of network drivers at 140% demand are lower than those at 90% demand.

It is apparent that from the results shown in Figure 4.4, Figure 4.5 and Figure 4.6 that, for this scenario, the VMS benefits to the incident drivers and non-incident drivers vary with traffic demand. There is clearly a window of general network traffic levels within which the maximum benefits may be achieved from VMS.

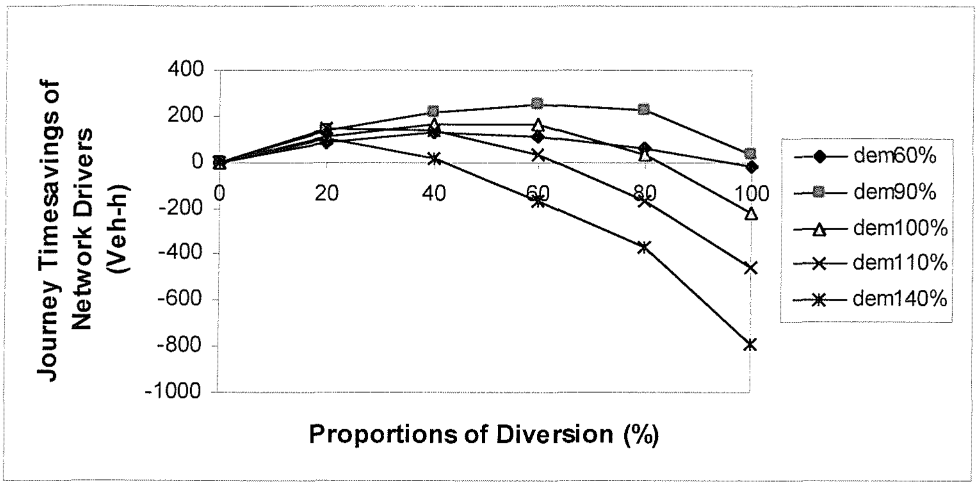

Figure 4.4 Network Benefits in conditions of varying demands

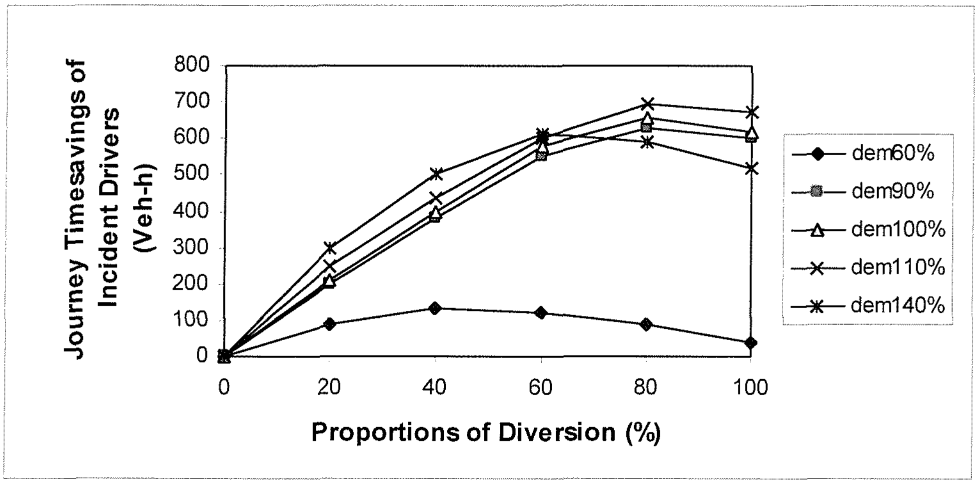

Figure 4.5 Benefits to Incident Drivers in conditions of varying demands

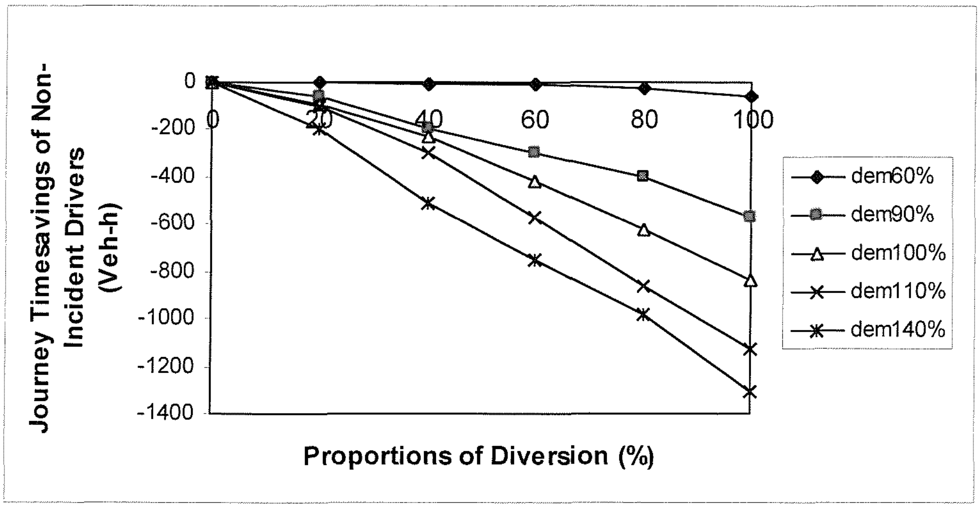

Figure 4.6 Benefits to Non-incident Drivers in conditions of varying demands

4.5 The effects of VMS in conditions of varying incident severity

The RGCONTRAM model was run to explore the effects of VMS in conditions of varying incident severity. Four levels of incident severity were investigated: 25%, 50%, 75% and 100%. A severity level of 50% represents one of the two lanes on Redbridge Causeway being closed. A severity level of 100% represents total road closure. Severity levels of 25% and 75% represent the situations of the road being partially blocked. The impacts of incident severity on drivers' benefits from VMS are illustrated inFigure 4.7, Figure 4.8 and Figure 4.9.

When no incident occurs on Redbridge Causeway, the traffic speed is 89 km/h and there is no queue on Redbridge Causeway during the time period of 08:00-09:00 AM. When in the incident scenarios, the traffic speed decreases and the queues increase as incident severity increases (Table 4.5). When one lane is blocked, for example, the traffic speed on the A35 on an incident link is reduced to 24 km/h and the incident causes a queue length of 222 vehicles between Redbridge Causeway and Hunters Hill Roundabout (with the storage capacity of 723 vehicles). When the road is closed, the traffic on incident route becomes stopped and the queue length increases to 601 vehicles during the incident.

Table 4.5 Traffic speed and queues on the incident route

Incident Severity	Incident , no VMS		
	Increase in Total Journey Time Caused By the Incident (veh-h)	Average Queues on the Incident Route (veh)	Average speed on the incident link during the incident (km/h)
0%	0 (0%)	0	89.7
25%	178 (1%)	222	24.3
50%	1057 (6%)	354	4.7
75%	2454 (15%)	475	1.9
100%	3791 (23%)	601	0.8

It is apparent from the results shown in Figure 4.7 that the network benefits of VMS increase as incident severity increases. At 25% incident severity, the maximum network journey time-savings are reached when 20% drivers divert and 34.5% of the additional journey time caused by the incident is recovered. As incident severity increases, such optimum diversion levels increase. At 100% incident severity, the maximum network benefits are reached at 80%

diversion level with the journey time-savings of 655.4 vehicle-hour, which account for 7% of the additional journey time caused by the incident (Table 4.6).

It may be seen from results shown in Figure 4.8 that incident drivers benefit, even those who do not divert because of the reduced congestion on the incident route. The journey time-savings of the incident drivers increases as incident severity and diversion levels increase (excluding minor incidents, e.g. severity < 25%). The results shown in Figure 4.9 indicated that non-incident drivers disbenefit with increasing incident severity, although, incident severity has little effect on their journey time. (Not all of the non-incident drivers disbenefit from diversion, at least those drivers travelling on the downstream link of the incident benefit from the increase in incident severity and their journey time savings increase as incident severity increases because of the reduced congestion).

The results shown in Figure 4.7 illustrate the importance of incident severity in strategy decisions. When the incident is 'severe', there is large potential for journey time savings from diversion and diversion benefit to network drivers. However, when a minor incident occurs, implementing a VMS strategy achieves very little or no network benefits and therefore implementation is not considered worthwhile.

Table 4.6 Benefits of VMS in conditions of varying incident severity

Incident Severity	Optimum Diversion Level (%)	Maximum Network Benefits (veh-h)	Network Percentage Recovery (%)
0%	0	0.0	0
25%	20	65.1	34.5
50%	40	167.0	15.7
75%	60	485.8	15.5
100%	80	655.4	7.0

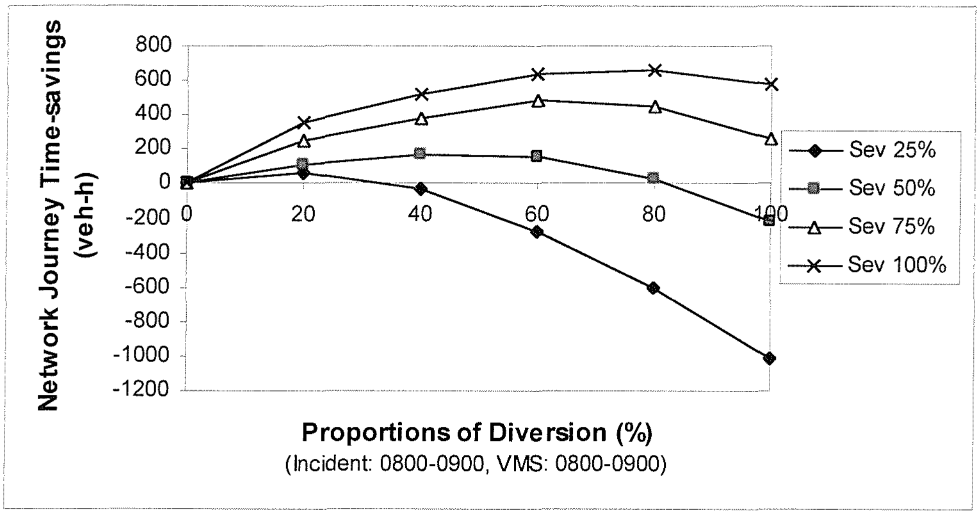

Figure 4.7 Network Benefits in conditions of varying incident severty

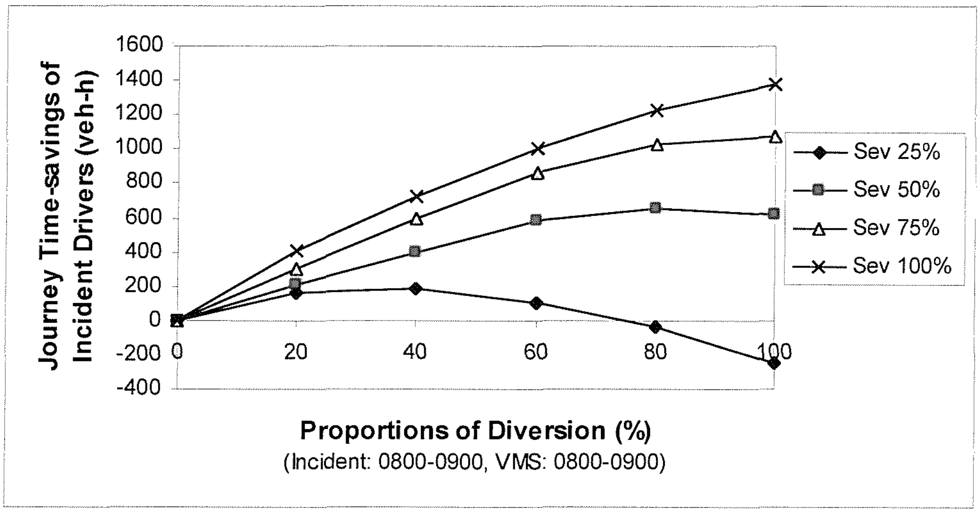

Figure 4.8 Benefits to incident drivers in conditions of varying incident severty

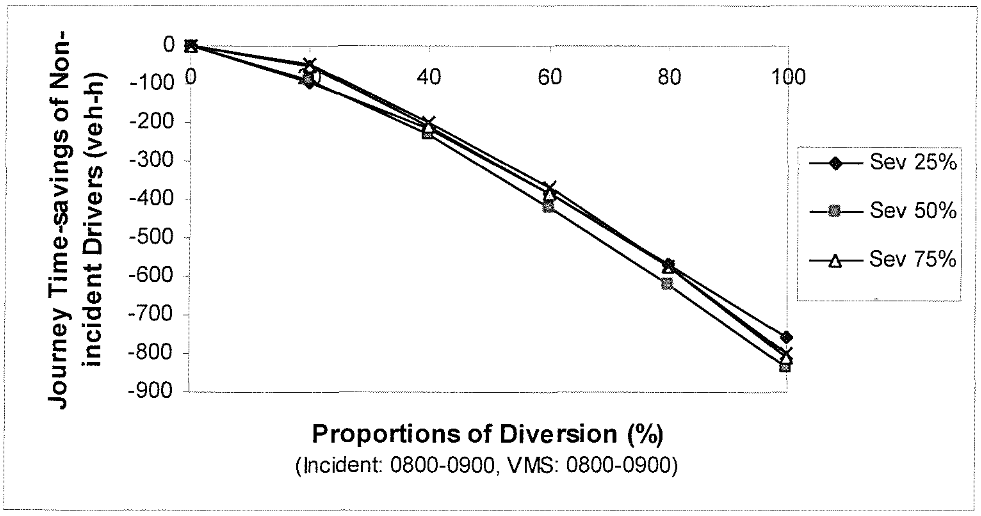

Figure 4.9 Benefits to Non-incident drivers in conditions of varying incident severty

The results in Table 4.7 show the average queues on the incident route of the A35 during VMS displays. It can be seen that incident severity has substantial impacts on queue lengths on the incident route. As incident severity increases, the queue length increases. Checking the traffic results on the A35 indicates that no queues stretch back to Hunters Hill Roundabout (decision point for those drivers passing VMS H01 and H02, Figure 4.1) during VMS displays when the incident severity is lower than 50%. However, the route of the A35 become full and the queues stretch back to Hunters Hill Roundabout when the incident is more severe than 75%, especially when drivers divert at low levels.

Table 4.7 Average queues on the incident route of the A35 during the incident

		Diversion Levels					
		0%	20%	40%	60%	80%	100%
Incident Severity	25%	222	102	0	0	0	0
	50%	354	343	330	295	227	128
	75%	475	438	383	320	307	289
	100%	601	491	458	416	424	336

4.6 The effects of VMS in conditions of varying incident duration

To investigate the impacts of incident duration on the benefits of VMS, the traffic scenarios with one lane being blocked on Redbridge Causeway during varying time periods were modelled. Eight possible incident durations from 15 minutes to 120 minutes were investigated. In modelling, VMS duration was set to coincide with the corresponding incident.

As shown in Table 4.8 that in 'do nothing' scenarios, the queues and delays on the incident route increase as incident duration increase. For example, when the incident lasts for 15 minutes, the incident causes a queue length of 163 vehicles on the incident route and 68 vehicle-hour of additional network journey time. When the incident duration is 120 minutes, the queue length and the additional network journey time increases to 522 vehicles and 2312 vehicle-hour respectively.

The journey time-savings of different driver groups are illustrated in Figure 4.10. It can be seen that the journey time-savings of the incident drivers increase as the incident duration increases. This is because the longer the incident, the more queues and delays there are on the incident route and the more potential of journey time-savings from diversion for diverting drivers. Although the non-incident drivers disbenefit from diversion, the increase in their journey time is less than the journey time-savings of the incident drivers as the incident duration increases. This results in network journey time-savings increasing, as incident duration increases.

It may be seen from Figure 4.10 that no network benefits come from diversion when the incident duration is shorter than 15 minutes (actually the network journet time increases by 31.7 veh-h). Because the short duration of the incident, the queues caused by the incident did not reach the level at which network drivers can benefit from the `diversion. The results highlight the importance of incident duration in the VMS strategies. When an incident of long duration occurs, large potential benefits of exist for diversion with a corresponding VMS strategy. However, when an incident of short duration occurs, implementing a VMS is likely to achieve little or no journey time-saving and is not worthwhile.

In practice, it is difficult to predict incident duration accurately. Many factors influence incident duration, including the approaches used for incident detection, the type and number of vehicles involved, the damage to persons and properties, the resources available for incident response and incident clearance.

Table 4.8 Queues in conditions of different incident duration

Incident Duration (min)	0	15	30	45	60	75	90	105	120
Incident without VMS									
Queues On Incident Route (veh)	0	163	258	355	393	452	471	498	522
Increase in Network Journey Time (veh-h)	0	67.9	524	778	1131	1484	1763	2076	2312
Incident with VMS									
Network Journey Time-savings (veh-h)	0	-31.7	201.4	297.4	288.4	370.4	437.7	573.9	748
Network Percentage Recovery (%)	0	0	38	38	25	25	25	28	32

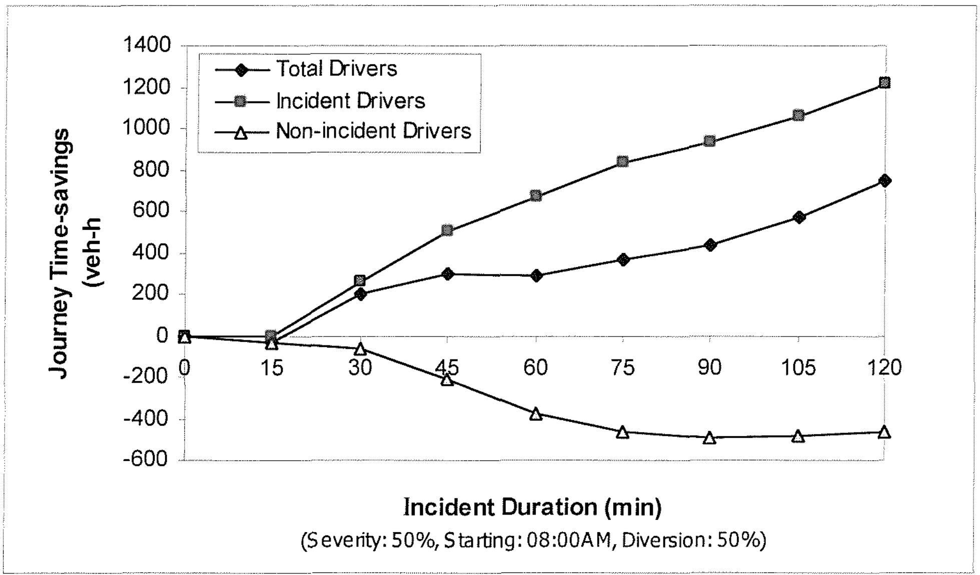

Figure 4.10 Journey time-savings in conditions of varying incident duration

4.7 In conditions of varying starting time of VMS display

An incident on Redbridge Causeway eastbound with one lane open during the time period of 08:00-09:00 was investigated to consider the influence of VMS starting time. Four strategies of VMS starting time were tested: coinciding with the incident; 10 minutes delay; 20 minutes delay and 30 minutes delay. The modelling results for each strategy are illustrated in Table 4.9 and Figure 4.11.

When VMS starting time is set to coincide with the incident, i.e. in 08:00-09:00, a maximum of 1378 vehicles could pass the VMS location and receive VMS information. As the delay of VMS display increases, this number decreases. When the delay is 30 minutes, only 677 vehicles pass the VMS locations.

The results in Figure 4.12 show that when less than 60% of the drivers divert, delaying the start of the VMS reduces the benefits to the network drivers. However, when more than 60% of drivers divert, the network journey time-savings increase as the delay of the VMS start time increases. When the VMS starting time is set to coincide with the incident, the maximum network benefits are reached when 40% of drivers divert and 15.8% of additional journey time caused by the incident is recovered. As the delay of VMS display increases, the maximum network benefits and the values of network percentage recovery (NPR) reduce.

The results in Figure 4.11 illustrate the importance of strategies in VMS start time. When small number of drivers divert, delaying the start of VMS reduces the network benefits of VMS. However, when large number of drivers divert, delaying the start of VMS can improve the network benefits of VMS.

In urban areas, the proportions of diversion with VMS are often low (Hounsell et al, 1998; Richard et al, 1999). Therefore, reducing delays of VMS activation is very important in urban VMS application. There are many factors which can influence the time of VMS activation including incident detection, VMS control and communication et al. Incident detection is one of the most important factors which can contribute to the reduction of VMS activation delays and increase the benefits of VMS display.

In reality, VMS are often activated with some delays. Either an incident has not been detected/reported straight away, or delay and congestion on incident routes have not reached a level at which diversion is needed to divert traffic from the incident location. In the late situation, it is difficult to pre-define the optimum time to switch on VMS because of the difficulty in predicting drivers' routing behaviours in responses to information. Network modelling is one of the more effective approaches to improve strategies for VMS operation

Table 4.9 VMS start time and its effects

Incident Duration: 08:00-09:00				
VMS duration	08:00-09:00	08:10-09:00	08:20-09:00	08:30-09:00
Maximum Number of Drivers Eligible to Divert (Veh)	1378	1146	818	677
Optimum Proportions of Diversion (%)	40	40	60	80
Network Percentage Recovery (NPR) (%)	15.8	13.3	12.6	11.2

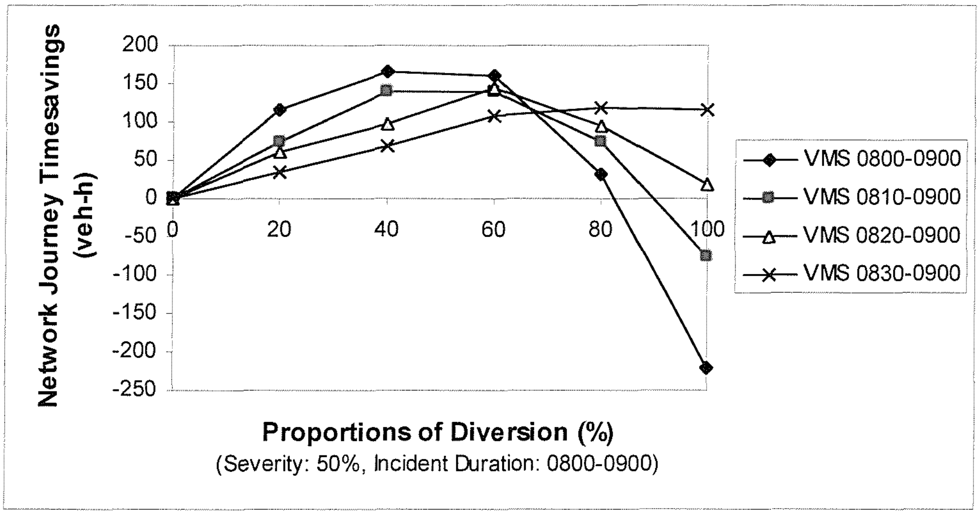

Figure 4.11 Network benefits in conditions of varying incident duration

4.8 In conditions of varying end time of VMS display

VMS duration determines the number of drivers who receive the information. To consider the impacts of VMS duration, six strategies were investigated for a one-hour incident on Redbridge Causeway eastbound, with VMS duration varying from 45 minutes ahead of the incident to 30 minutes beyond the incident.

When the VMS is displayed for 15 minutes (i.e. VMS is switched off forty-five minutes before the incident clearance), a maximum of 328 vehicles could potentially divert. As VMS duration increases, this number increases. When the VMS is extended to 30 minutes beyond the incident, 1780 drivers receive VMS information and could potentially divert (Table 4.10).

The benefits of VMS in terms of journey time-savings for network drivers, incident drivers, and non-incident drivers are illustrated in Figure 4.12, Figure 4.13 and Figure 4.14 respectively. The results in Figure 4.12 show that the network benefits vary with VMS duration and diversion levels. When less than 60% of the incident drivers divert, the network benefits increase as VMS duration increases. However, when more than 60% of the drivers divert, the network benefits decrease as VMS duration increases (excluding VMS duration shorter than 15 minutes). This is because when a low proportion of drivers divert, most incident drivers remain on their original route. The large queues on the incident route increases the potential journey time-savings of diverting drivers. In this situation, lengthening the VMS display increases the network benefits. However, when a high proportion of drivers divert (e.g. diversion level >60%), the traffic on the diversion route becomes congested because of the large number of diverting vehicles. The benefits to incident drivers decrease as VMS duration increases (Figure 4.13), whilst the disbenefits to non-incident drivers continue to increase (Figure 4.14). Consequently, the network benefits decrease as VMS duration increases.

It can be seen from the Figure 4.12 that extending the VMS duration beyond the incident does not significantly increase the benefits when a low proportion of drivers divert. However, extending VMS duration beyond the incident can cause substantial disbenefits when a high proportion of drivers divert.

As shown in Figure 4.12, the maximum network benefits in conditions of low diversions are reached at VMS durations longer than those for high diversions. At the 40% diversion level, for example, the maximum network benefits are reached when VMS are switched off thirty minutes after the clearance of the incident. However, at an 80% diversion level, the maximum network benefits are reached thirty minutes before the incident clearance. Although the optimum VMS duration varies with diversion levels, there is not much difference in the values of NPR for each strategy of VMS duration investigated (excepting for the very short VMS duration, e.g. fifteen minutes).

Since in practice, diversion rates are typically low (Richard et al, 1999; Firmin et al, 1999), coinciding the VMS with an incident or extending the VMS duration beyond the incident is likely to be beneficial.

Table 4.10 Varying VMS ending time

Incident Duration: 08:00-09:00						
VMS Ending Time	08:00 / 08:15	08:00 / 08:30	08:00 / 08:45	08:00 / 09:00	08:00 / 09:15	08:00 / 09:30
Maximum Number of Drivers Eligible to Divert	328	701	1036	1378	1653	1870
Optimum Proportions of Diversion (%)	100	80	60	40	40	40
Maximum Network Benefits (veh-h)	154	180	173	167	179	180
Network Percentage of Recovery (%)	14.6	17.0	16.4	15.8	16.9	17.0

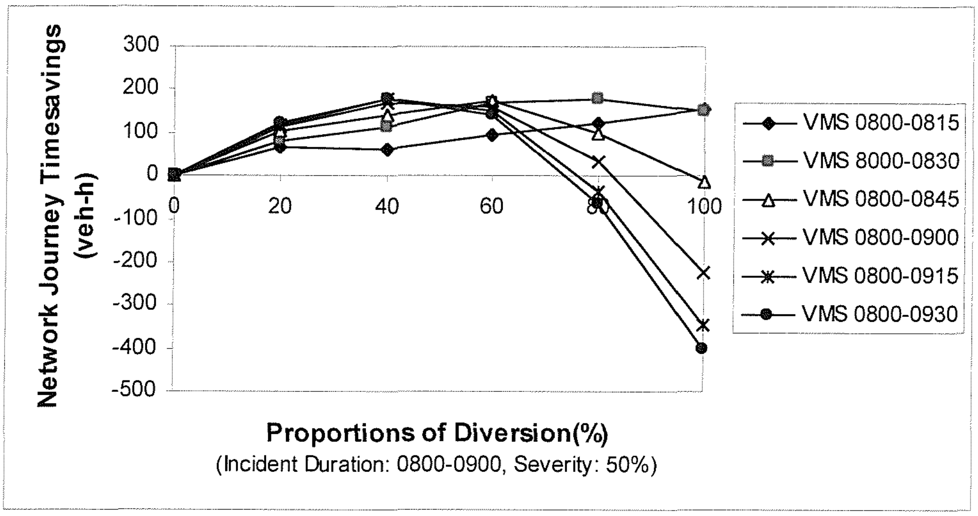

Figure 4.12 The network benefits in conditions of varying vms duration

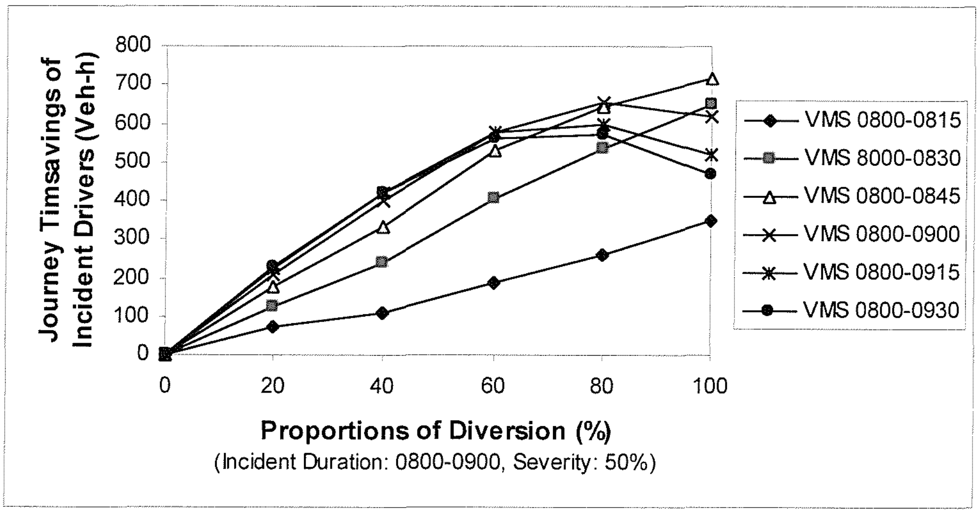

Figure 4.13 Benefits to incident drivers in conditions of varying VMS duration

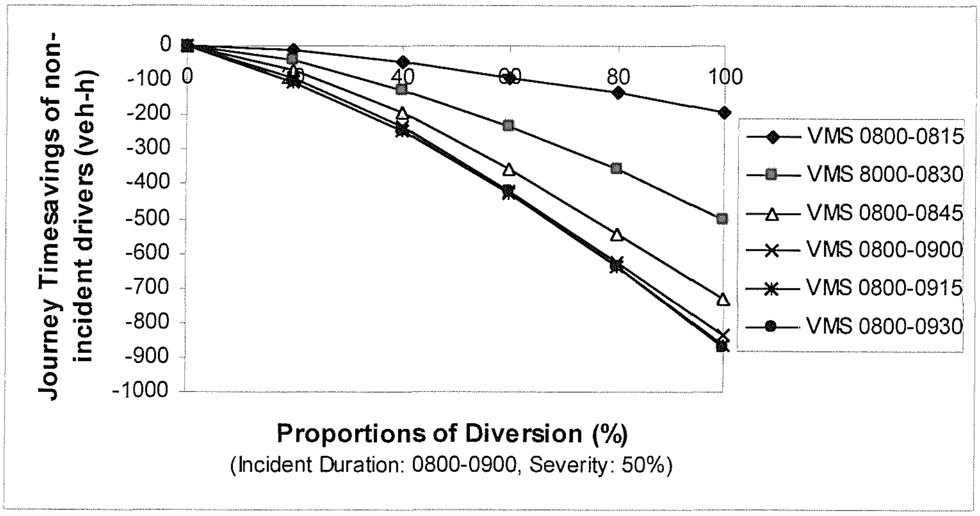

Figure 4.14 Benefits to Non-incident drivers in conditions of varying VMS duration

4.9 Conclusions

The effects of VMS are dependent on many factors including demand, incident severity, incident duration, VMS duration and diversion routes. Based on the modelling results, the following conclusions can be drawn relating to the effects of VMS on the network benefits of diversion:

- The relative congestion level on incident routes to that on diversion routes is one of the key factors which determine the benefits of VMS. When diversion routes are less congested than incident routes (e.g. when no diversion or at initial stages of the diversion), implementing a VMS strategy can make drivers benefit from diversion because of the shorter journey time using diversion routes. However, when congestion levels on diversion routes are equal to or higher than those on incident routes (e.g. minor incidents and large number of vehicles being diverted to the alternative routes), there is very little chance for drivers to benefit from diversion by VMS.

- In general, incident drivers benefit from diversion, including those incident drivers who do not divert because of the reduced congestion on the incident route. Non-incident drivers disbenefit from diversion especially those travelling on the main diversion routes. Network benefits arise when the benefits to incident drivers outweigh the disbenefits to non-incident drivers.

- Traffic demand is one of the most important factors which influence the routing effects of VMS. For given network and incident, there is more congestion on incident routes and less spare capacity on diversion routes when at high demand; however, there is less congestion on incident routes and more spare capacity on diversion routes when at low demand. So, there is clearly a window of traffic demands within which the maximum network benefits may be achieved from deploying the appropriate VMS strategies.

- Incident severity and duration are the two elements which have key influences on the congestion levels on incident routes. When a minor and short incident occurs, there is few queues on the incident route, too much diversion may result in the remaining capacity of the incident link not being fully used. However, when a more severe and longer incident occurs, there are lareg numbers of queues caused by the incident which increases the potential benefits of diversion. This highlights the importance of incident characteristics in strategy decisions. When the incident is severe or longer, there is large potential of network journey timesavings from diversion. However, when a minor or short incident occurs, implementing a VMS strategy achieves very little or no network benefits and therefore implementation is not considered worthwhile.

- VMS duration is one of the most important factors which influence influence the number of drivers who receive VMS information. Both delaying VMS activation and extending VMS duration beyond incidents can increase/decrease the benefits of diversion. For incidents causing large number queues, early detection and VMS activation is vital for increasing the benefits of VMS. Any delays mean that the benefits of the VMS are reduced.

- The benefits of VMS have been derived by comparing journey times in the incident scenario with those in the base scenario, i.e. "do nothing" scenarios in which it is assumed that no diversion occurs. This is unlikely to be wholly true in reality. Some drivers might divert when they encounter additional queues on their original route (although such routing decisions might take longer time than the informed decisions using VMS information). Because the current knowledge of drivers' routing responses to congestion has not reached to the stage in which an accurate estimation can be made, no pre-defined value has been made for drivers' diversion in response to congestion in this modelling. Therefore, the modelling results of VMS benefits might be overestimated by the extent to which some drivers divert because of observed congestion. This will be greatest when the traffic and severity are greatest. (In the scenarios modelled, queues block back to decision points when the incident severity is higher than 75%, whilst the typical incident severity modelled in this research is 50%)

- The congestion level caused by incidents is one of the most important factors for operators to consider when making decisions on VMS strategies. Incident severity, incident duration, incident location, traffic demand and diversion levels et al all have some influences on such congestion. However, it is difficult to establish the effects of individual factors in isolation, because these factors are interacted each other in reality.

5 Network monitoring and data collection

5.1 Introduction

From 01/08/99 to 20/12/00, information on incidents occurring in Southampton were collected. This included traffic information and VMS strategies in details. In this section, the data collection process and the main results of the subsequent analysis are presented.

5.2 Traffic monitoring

Prior to ROMANSE (Road MANagement System for Europe) project, Southampton had an extensive monitoring system based on the SCOOT Urban Traffic Control (UTC) system, with over 100 signalised junctions and 600 detectors. Most of the traffic signal junctions within the urban network operate under the SCOOT adaptive method of UTC control. Inductive loops are located on most approaches to all junction and pedestrian traffic signal controllers. These loops measure occupancy every quarter of a second from which flow may be estimated in real-time.

There are some 300 other loops located in Southampton at locations where count information is required, or where queue detection is important. These loops also provide real-time data to the UTC system. Where single SCOOT detectors monitor more than one lane, the recorded traffic flows can be inaccurate (because of masking effects of traffic), the relevant count detectors can be important.

ROMANSE has 30 Closed Circuit Television (CCTV) cameras strategically placed throughout its region of influence. These cameras cover both urban and inter-urban sites, and are extensively used for determining road conditions and incident management.

In Southampton, road traffic incidents in urban network can be detected automatically using the INGRID algorithm (Bowers et al, 1995). This operates within the Integrated Traffic Management Computer (ITMC) systems and utilises the behaviour of traffic on adjacent SCOOT detectors throughout the signalised area. The algorithms work in real-time and identify events which are abnormal both in absolute terms and also with reference to long term profiles of expected conditions. Incidents identified by the police are received automatically through the Travel Terminal network and are subsequently passed to the Travel and Traffic Information

Centre (TTIC). In addition to the above methods, the TTIC is manned throughout the day by operators who can identify incidents from CCTV, from public by telephone, and from television/teletext.

5.3 Traffic data

The main objective of the traffic data collection undertaken for this thesis has been for off-line analysis of incident/VMS, to investigate whether and how traffic conditions change during VMS' activation, compared to usual traffic conditions. Between 01/08/1999 and 20/12/2000, traffic data from detectors have been regularly collected and stored every day in Southampton. Because of the memory limitation in the UTC computer, only peak period data were collected between 01/08/99 and 30/06/2000 (AM peak from 07:00 to 09:30 and PM peak from 16:00-18:00). This prohibit the analysis to those incidents which occurred during non-peak periods or those incidents whose duration extended beyond peak periods. Since 01/07/00, 15 hour traffic data have been collected which covers the time period from 07:00AM to 22:00PM. Such a wide period of traffic data has increased the possibility for all the major incident scenarios to be analysed.

The traffic data collected were the newly developed U06 and U07 SCOOT messages, which provide the following six kinds of data:

- traffic flow (veh/h)
- average speed over detector (km/h)
- average speed over detector (m/h)
- average occupancy of detector (%)
- average loop occupancy time per vehicle (ALOTPV)
- average headway time between vehicles (AHTBV).

U06 gives an output every 30 seconds, while U07 gives an output every 5 minutes. Traffic flow, speed and occupancy are very useful in analysing traffic status during the incident, especially for defining queue status and calculating diversion rates. The ALOTPV and AHTBV data can be used together to provide a measure of "congestion".

All the raw SCOOT data collected have been processed and stored (in Excel files by location and time). These traffic data can be used for both immediate purposes of incident case studies and for medium and long-term studies to ascertain trends in drivers' response to VMS information. In this research, the traffic data collected has been used mainly to study drivers' diversion response to VMS information.

To understand day-to-day variations of traffic flow, detector data in normal traffic conditions (i.e. without incidents) have been analysed. The sample data were from main corridors in Southampton, including A33, A35, A335, A3024 and A3057 (Figure 5.1). Ten detectors were selected from the five corridors, one for each direction. The sample data were from 07:00 to 22:00 on weekdays in November 2000. The analysis was focused on the traffic in the three different time periods: AM peak period of 07:00-09:00, PM peak period of 16:00-18:00, and non-peak period of 09:00-16:00.

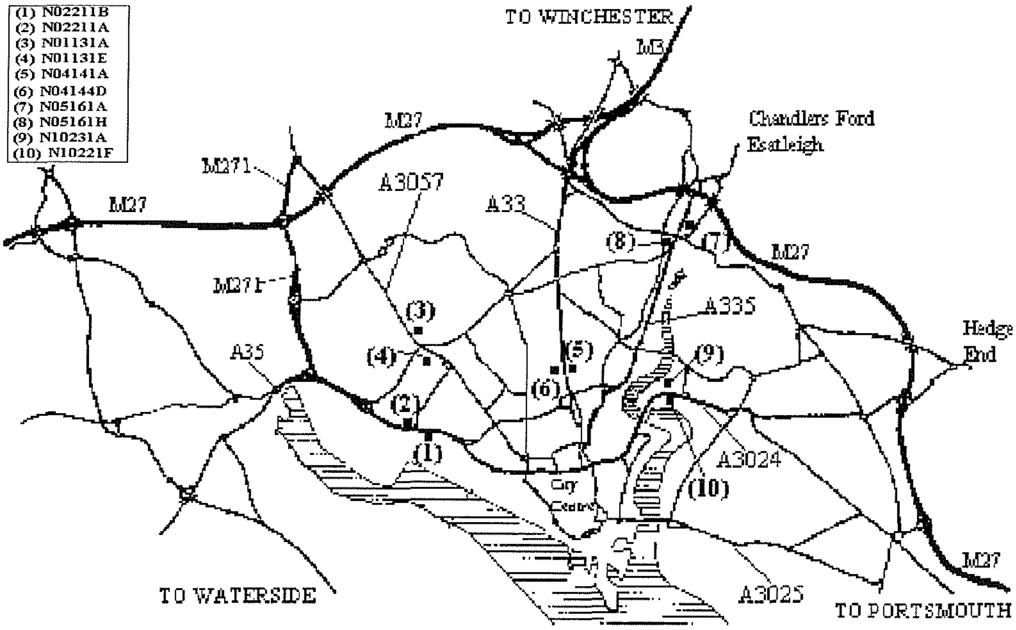

Figure 5.1 Locations of sample detectors

The results of the data analysis show that traffic varies from day to day. Taking the traffic from detector N02211A as an example, the results in Figure 5.2 show the distribution of the total traffic in the period of 07:00-22:00 on weekdays. It can be seen that the total traffic is different between different days. Statistics test was conducted to see whether the difference was significant. The null hypothesis was that there is no significant difference between the observed traffic with the mean traffic. The results are shown in Table 5.1. According to the test results, the difference between observed traffic and the mean traffic is statistically significant (t=0.679, df=18, p=0.506, α=0.05). The null hypothesis is rejected at 5% significant level.

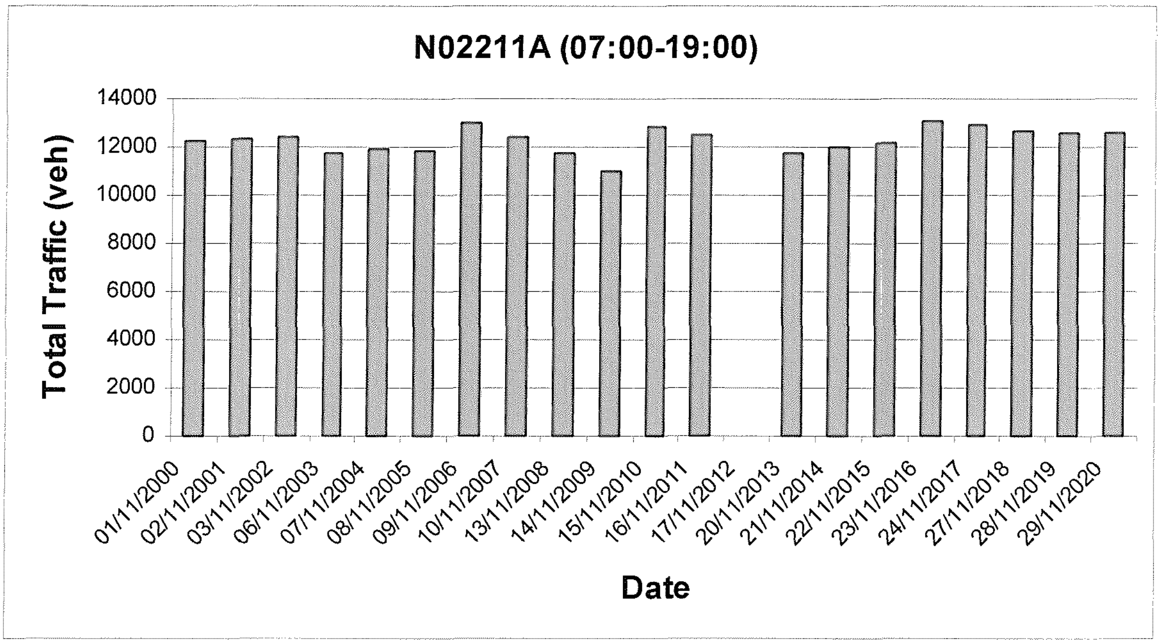

Figure 5.2 Distributions of weekday traffic flow on Millbrook Road eastbound

Table 5.1 Results of statistics test

	Test Value = 12282					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N02211A	.679	18	.506	68.2105	-142.7866	279.2077

The traffic data from N02211A were further analysed by examining the traffic flow in different time periods. The results in Table 5.2 show the distribution of the traffic flow in the time period from 07:00 to 19:00. It can be seen that the traffic flows in AM peak are less spread about the mean than those in other periods. The average standard deviation in AM peak period is 28.20 veh/h, compared with 47.03 veh/h in PM peak period and 58.15 veh/h in non-peak period.

Table 5.2 Distributions of traffic flow (N02211A) in different time periods

	07:00-08:00	08:00-09:00	09:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00
Mean (veh/h)	1383	1750	1708	1329	1308	1205
Standard Deviation (veh/h)	37	28.20	46	49.19	58	73

	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19:00
Mean (veh/h)	1201	1106	999	1073	938	892
Standard Deviation (veh/h)	60	47	80	52	47.03	63

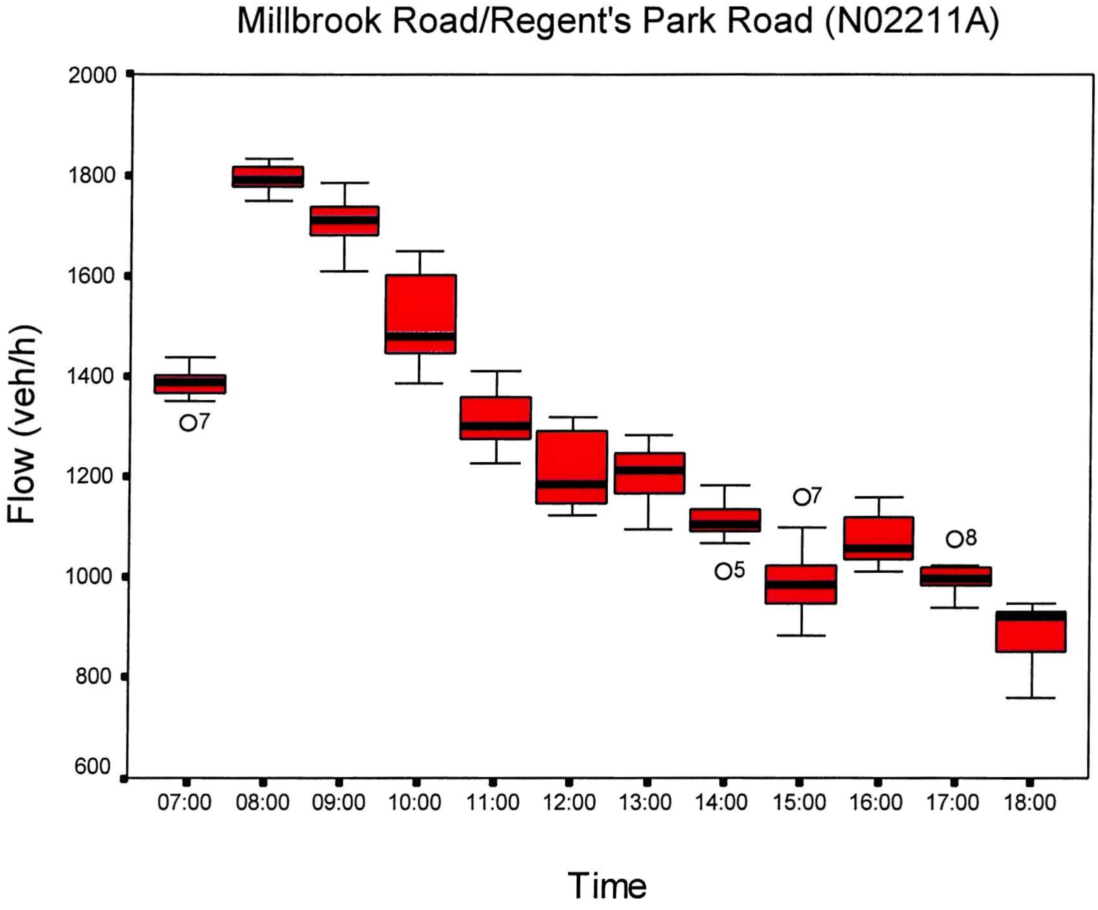

Figure 5.3 Distributions of the mean traffic flows (N02211A)

Similar analysis has been done for the other nine detectors. The results in Table 5.3 show the summary of the statistics analysis. The average standard deviation of traffic flows in AM peak period is 39.70 veh/h, compared with 53.79 and 60.57 veh/h in non-peak and PM peak periods respectively. It can be seen that the day-to-day variations in traffic flow change with detector locations and time periods (Figure 5.3). Traffic flows in AM peak are less spread about the mean than those in other time periods. This is very important for analyssing driver's diverting responses to VMS. It is easier to identiy diverting traffic from stable traffic than from less stable traffic. From this point of view, incident cases occuring in AM peaks can provide more opportunities for identifying diverting traffic with higher accuracy than in other peak periods.

Table 5.3 Summary of statistics results for the detector data analysed

		N	Minimum	Maximum	Mean	Std. Deviation
N01311E	AM	14	417	527	482.21	30.54
	NP	20	379	448	407.40	20.30
	PM	20	634	734	686.10	31.97
N01131A	AM	14	818	933	865.75	31.61
	NP	20	582	694	620.00	27.28
	PM	20	644	730	689.15	22.96
N02211A	AM	14	1750	1848	1799.08	28.20
	NP	20	1329	1649	1484.05	49.19
	PM	18	938	1282	1037.39	47.03
N02211B	AM	14	977	1109	1047.57	46.67
	NP	20	670	934	826.25	55.26
	PM	20	1417	1629	1553.83	61.42
N05161H	AM	14	1527	1740	1621.22	63.94
	NP	19	982	1260	1100.11	83.65
	PM	20	1091	1486	1271.40	100.19
N05161A	AM	14	2278	2498	2364.33	69.04
	NP	20	1396	1627	1518.05	58.91
	PM	20	1946	2320	2103.21	94.61
N10231A	AM	11	747	822	780.45	22.05
	NP	20	524	826	752.95	79.27
	PM	17	1421	1622	1521.76	60.50
N01221F	AM	11	1799	1929	1860.36	39.99
	NP	20	826	1196	1116.50	82.58
	PM	17	726	948	801.24	65.51
N04144D	AM	14	681	782	737.45	29.23
	NP	16	637	755	687.81	33.88
	PM	119	1043	1206	1114.40	43.94
N04141E	AM	14	1032	1172	1115.50	35.72
	NP	20	817	998	891.65	47.60
	PM	20	654	966	765.90	77.53

5.4 Incidents occurring in Southampton

Traffic in and around Southampton has been continuously monitored by the ROMANSE office. When an incident occurs, traffic information concerning incidents is reported ans sent out by the ROMANSE office in "TrafficNews" which was one of the major sources of information about incidents in this research. In addition, detailed information on accidents was obtained from the accident logs of the police. In this research, the main information collected on incidents was:

- incident cause;
- incident location;
- incident severity;
- incident starting time and duration;
- congestion caused by the incidents.

(i) Space distribution of incidents

During the period from 01/08/1999 to 20/12/2000, 1040 incidents occurred in and around Southampton for which VMS were used (Minor incidents without VMS message display were not included). Of the incidents that occurred, 61% were on urban roads and 39% were on motorway/trunk roads (Figure 5.4). On average, there were 2.1 incidents in the urban area of Southampton each day.

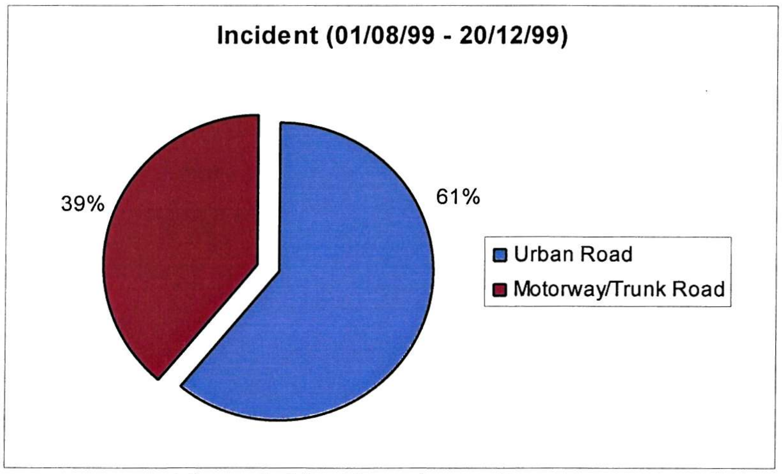

Figure 5.4 Incidents by road type

In Southampton, the central area is reached by several corridors including the A33, A35, A335, A3024 and A3057 (Figure 5.5). Of the 635 reported urban road incidents, 91% of them occurred on these corridors, which highlights the importance of corridor incidents in this study.

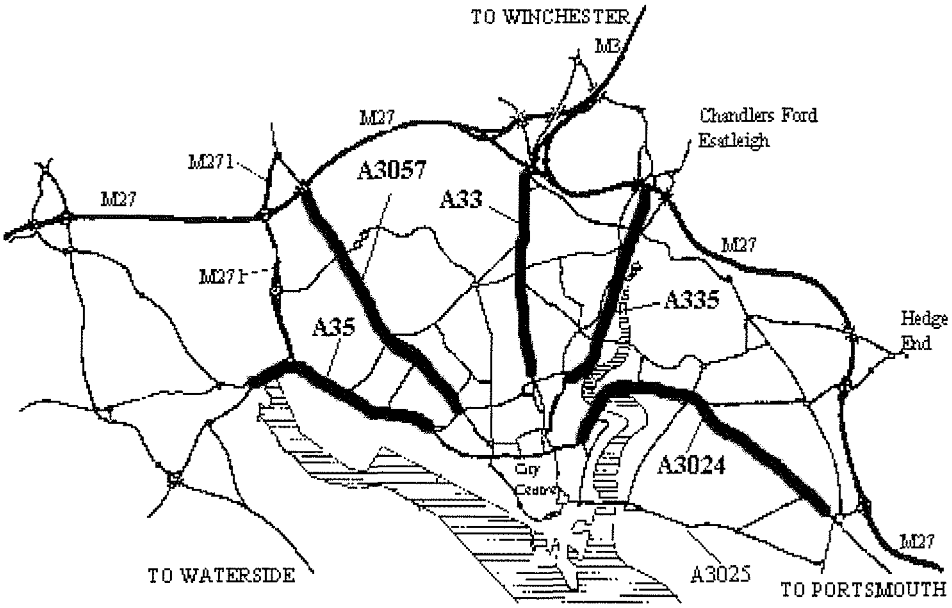

Figure 5.5 Major corridors in Southampton

Figure 5.6 shows the distribution of incidents between the main corridors in Southampton. It can be seen that the incidents are not distributed evenly. About 70% occurred on the A35 and the A3024. The A35 is dual carrigeway with two and three lanes in each direction which carries the largest volume of traffic on the urban road network in Southampton. During the study period, 28 sets of roadwork projects conducted on the A3024 with 246 roadwork days in total. Roadworks accounted for 90% of the incidents on the A3024.

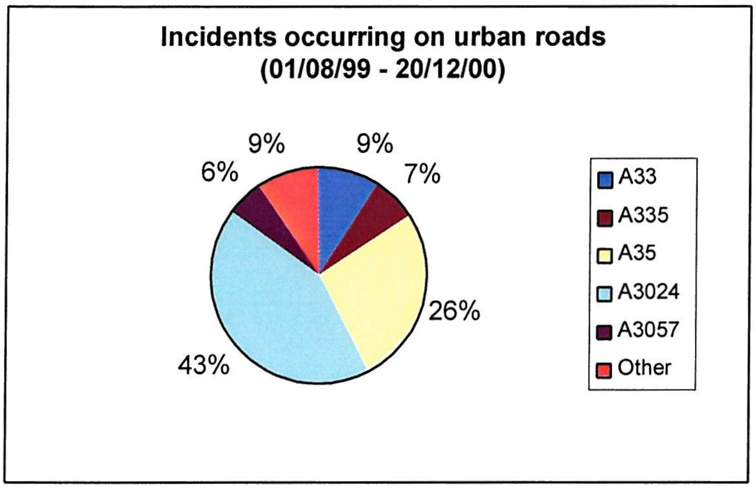

Figure 5.6 Incident distributions by corridors

(ii) Incident causes

Incidents were categorised into the following main types:

- Roadworks
- Road traffic accidents (RTA)
- Broken-down vehicle
- Vehicle shed load
- Other (special events and adverse whether e.g. fog, flood)

As can be seen from Figure 5.7 that roadworks and accidents were the main cause of incidents occurring in the study period and accounted for 64% and 27% of the incidents respectively. In urban areas, 70.2% of the incidents were roadworks, 17.5% were accidents, compared with equivalent values of 52.1% and 42.5% on motorways (Table 5.4). There were more roadworks and less accidents on urban roads than on motorways.

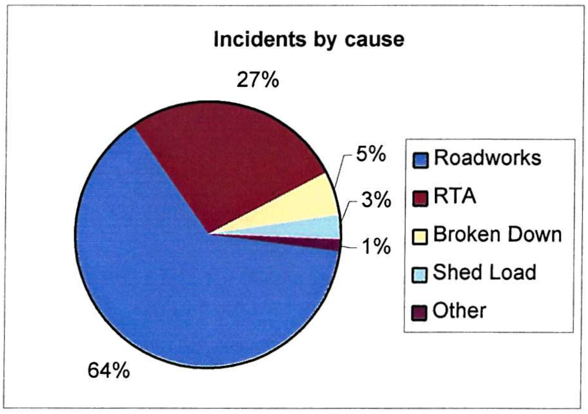

Figure 5.7 Incidents by cause

Table 5.4 Incidents by cause

	Urban Road	Motorway
Roadworks	445 (70.2%)	211 (52.1%)
RTA	111 (17.5%)	172 (42.5%)
Brokendown	42 (6.6%)	11 (2.7%)
Shed Load	26 (4.1%)	8 (2.0%)
Other	11 (1.6%)	2 (0.4%)
Total	635 (100%)	405 (100%)

(iii) Incident severity

Incident severity is an important factor affecting delays and congestion. For the urban incidents reported, the distributions of incident severity are shown in Table 5.5. It can be seen that 'one lane blocked' during incidents was the most frequent incident severity.

Table 5.5 Incident severity in urban areas

Incident Severity	Distribution
One of the two lanes blocked	590 (93.1%)
One of the three lanes blocked	28 (4.4%)
Two of the three lanes blocked	0 (0%)
Road Closure	17 (2.5%)

Because most of roadworks were planned, most were organised to try to avoid road closure. Of the 445 of urban roadwork incidents, only 3.7% involved road closure in both directions, and in most cases, at least one lane left open.

(iv) Incident occurrence

The distribution of incidents between weekdays and weekends are shown in Table 5.6. It can be seen that the number of incidents is higher in weekdays than those at weekends (Figure 5.8). On urban roads, there were 540 incidents in weekdays and 95 incidents in weekends during the study period of 01/08/99-20/12/00. On average, 1.49 incidents occurred every weekday and 0.65 incident occurred every weekend-day. The corresponding figures on the motorway sections were 0.57 and 0.26 respectively.

Table 5.6 Number of incidents weekdays and weekends

		Roadworks	RTA	Brokendown	Shed Load	Other
Urban Road	Weekdays	375	99	36	19	11
	Weekends	72	12	6	2	3
Motorway	Weekdays	95	128	11	5	3
	Weekends	24	14	0	0	0

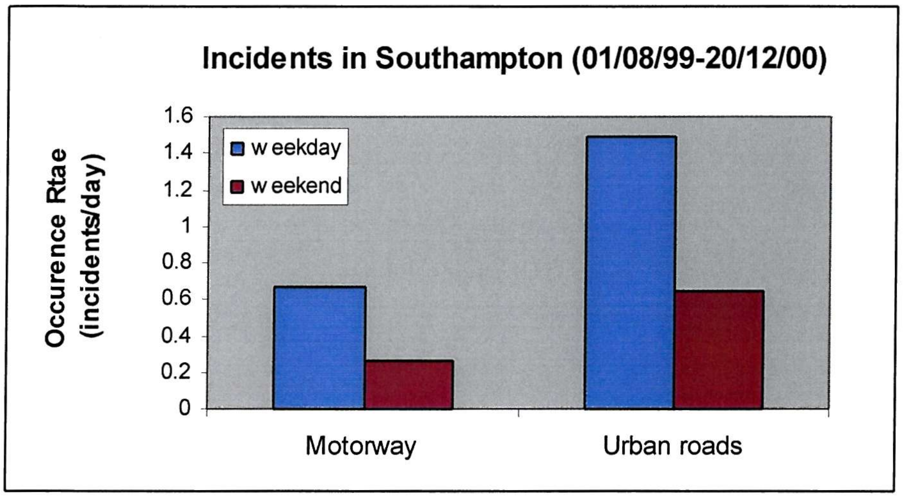

Figure 5.8 Occurrence rates of incidents in Southampton

Most roadworks were planned projects which started either in the early morning or during the non-peak periods. However, other incidents such as accidents occurred more randomly. Of the accidents occurring in urban areas, 20% occurred during the AM peak period (07:30-09:30), and 43% occurred during PM peak period (16:00-19:00) (Figure 5.9). 81.8% of urban accidents involved inbound traffic during the AM peak period, and 48.8% involved outbound traffic during the PM peak period (Table 5.7).

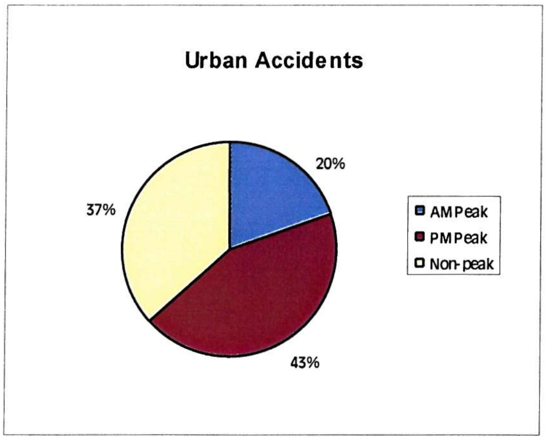

Figure 5.9 Incident occurrence

Table 5.7 Incidents by traffic direction

AM Peak (07:30-09:30)			PM Peak (16:00-19:00)		
Inbound	Outbound	Both Direction	Inbound	Outbound	Both Direction
18 (81.8%)	1 (4.5%)	3 (13.6%)	14 (34.1%)	20 (48.8%)	8 (19.5%)

(v) Incident duration

An incident duration is the time from the occurrence of the incident to its clearance. The mean duration of the four main types of incidents in urban areas is shown in Table 5.8. Roadworks have the longest duration and broken-down vehicles have the shortest duration. During the study period, 82 roadwork projects were carried out on urban roads with 447 roadwork-days in total. The duration of roadworks projects was dependent on the projects involved. Minor roadworks project were finished within a day, whilst major ones lasted for several days. (In this research, each roadwork-day was taken as an incident). On average, the duration of a roadwork incident was 8.2 hours.

Table 5.8 Incident duration for urban areas

Incident	Mean Duration
Roadworks	8.2 hours
Accident	28.0 min (n=108, StD.Dev=21.78)
Brokendown	22.5 min (n=36, StD.Dev=18.28)
Shed Load	24.4 min (n=16, StD.Dev=20.71

The duration distributions of accidents shows that the frequencies decrease as duration increases (Figure 5.10). Of the accidents, 37% had duration longer than 30 minutes and only 9.3% had duration longer than 60 minutes.

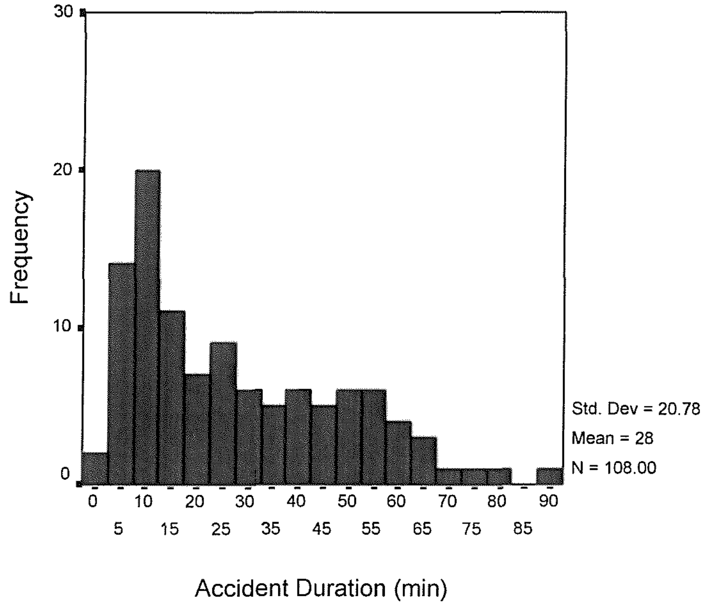

Figure 5.10 Distributions of incident duration

5.5 VMS log

During the study period of 01/08/99 to 20/12/00, all the VMS strategies used for each incident were collected and stored. At present, a total of 26 route guidance VMS have been installed in the urban areas of Southampton, primarily on key inbound routes to the city centre, although a few have been located to serve exiting traffic. Operation of these VMS is the responsibility of the operators based in the ROMANSE Project Office in the central Southampton. An additional 17 signs have also been installed on the M27 motorway, which borders Southampton to the north. Whilst these signs mostly provide information relating to conditions on the motorway, these also provide information relating to routes in Southampton, as and when required. The motorway signs are jointly controlled by the Police (based in Winchester of Hampshire) and the ROMANSE office. Southampton and surrounding areas now have a comprehensive coverage of route guidance VMS. The location of the VMS in and around Southampton is shown in Figure 5.11.

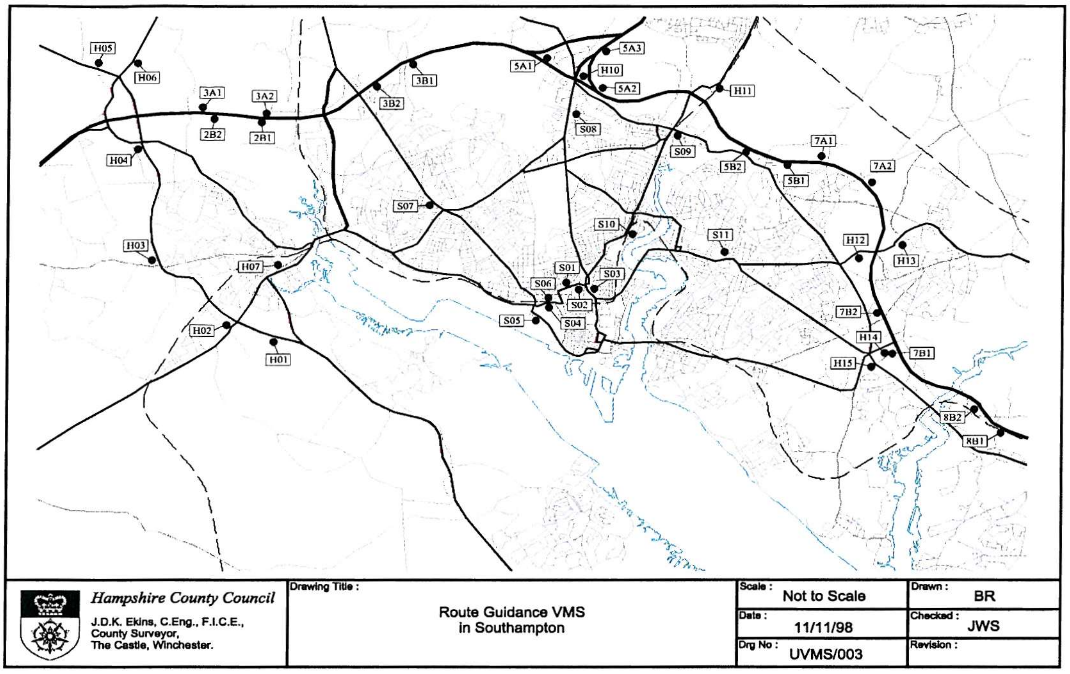

Figure 5.11 Locations of VMS in and around Southampton (Richard et al, 1999)

The VMS system has an interface via which operators can monitor the traffic and set the messages. Within the ROMANSE project, a library of strategies for all the major potential incident locations has been constructed based on an O-D matrix and modelling results. For each incident location, the VMS relevant to drivers approaching that location from each direction have been identified from modelling work. Each specific combination of incident location, cause and severity resulted in a specific set of VMS messages. Each unique combination is termed as a strategy. In the case of an incident, operators display and update VMS messages to inform drivers of current traffic conditions affected by the incident. The strategies include approximately 100 pre-programmed messages for a number of hypothetical scenarios, including accidents, broken-down vehicles, and roadworks (see Appendix B for VMS strategies in detail). Currently, the main VMS messages regarding the status of congestion/advice include:

- SHORT DELAYS
- DELAYS
- LONG DELAYS
- DELAY EASING
- ROAD CLOSED
- AVOID IF POSSIBLE

- USE DIVERSION

When an incident occurs, the strategies used for the incident are recorded by operators in the ROMANSE office. These logs provide detailed information about the VMS signs activated, the messages displayed and the time period for each VMS message during the incident. This information is very important for the analysis of drivers' diversion responses to VMS information.

5.6 Conclusions

Overall, Southampton provides a good traffic monitoring and data collection basis for studying drivers' responses to VMS in real conditions. Based on the results of monitoring and data process, the following conclusions can be drawn relating to incidents and VMS displays which occurred in Southampton:

- On average, there are two reported incidents each day which cause significant traffic delays and congestion in and around Southampton. Accidents and roadworks were the main incidents. On average, there was an accident every five days and a roadwork every day.

- 91% of incidents on urban roads occurred on the major corridors which connect surrounding areas with Central Southampton. These corridors were vulnerable because of the high speed and large volumes of traffic. Most serious delay and congestion were found occurring on these corridors.

- Currently, most VMS on urban roads are primarily on key inbound routes to the city centre, which made incidents involving inbound traffic more valuable for this study.

- About 40% of the incidents occurred on motorways. However, these cases were not analysed in detail because of the lack of detection on the motorway sections.

6 Drivers' responses to VMS in real conditions

6.1 Introduction

This section describes the study results of driver's diversion response to VMS in real traffic conditions. The approach used was as shown in Figure 6.1. Firstly, 'Traffic News' (Faxes sent to TRG by the Southampton ROMANSE office) was checked to determine whether suitable incidents likely to cause significant congestion had occurred. Secondly, traffic conditions when VMS strategies were activated were compared with normal traffic conditions. Diversion rates and statistical test were then calculated. Finally, the relationship between diversion rates and the VMS messages displayed was analysed.

Three kinds of network monitoring techniques were used: SCOOT detectors, count detectors and CCTV cameras. In addition, 12-hour manual count data from Southampton City Council were used to assess the accuracy of the detector results. Traffic data describing normal conditions were calculated by averaging the traffic data over a period of at least two weeks which cover the incident.

VMS information is usually disseminated to improve network efficiency by encouraging drivers to use alternative routes. Therefore, the diversion rate of traffic, i.e. the percentage of traffic diverting from incident route to alternative route, is particularly important.

Incidents which occurred on the A33, A35, A335 and A3024 routes were considered in particular as these four corridors connect central Southampton with the major dormitory areas of Chandlers Ford, Waterside, Eastleigh and Hedge End respectively. These were areas in which questionnaire and travel diary surveys had been previously conducted (Richard A et al, 1999). Because most VMS in Southampton are at locations best able to serve inbound traffic, only those incidents affecting inbound traffic were analysed.

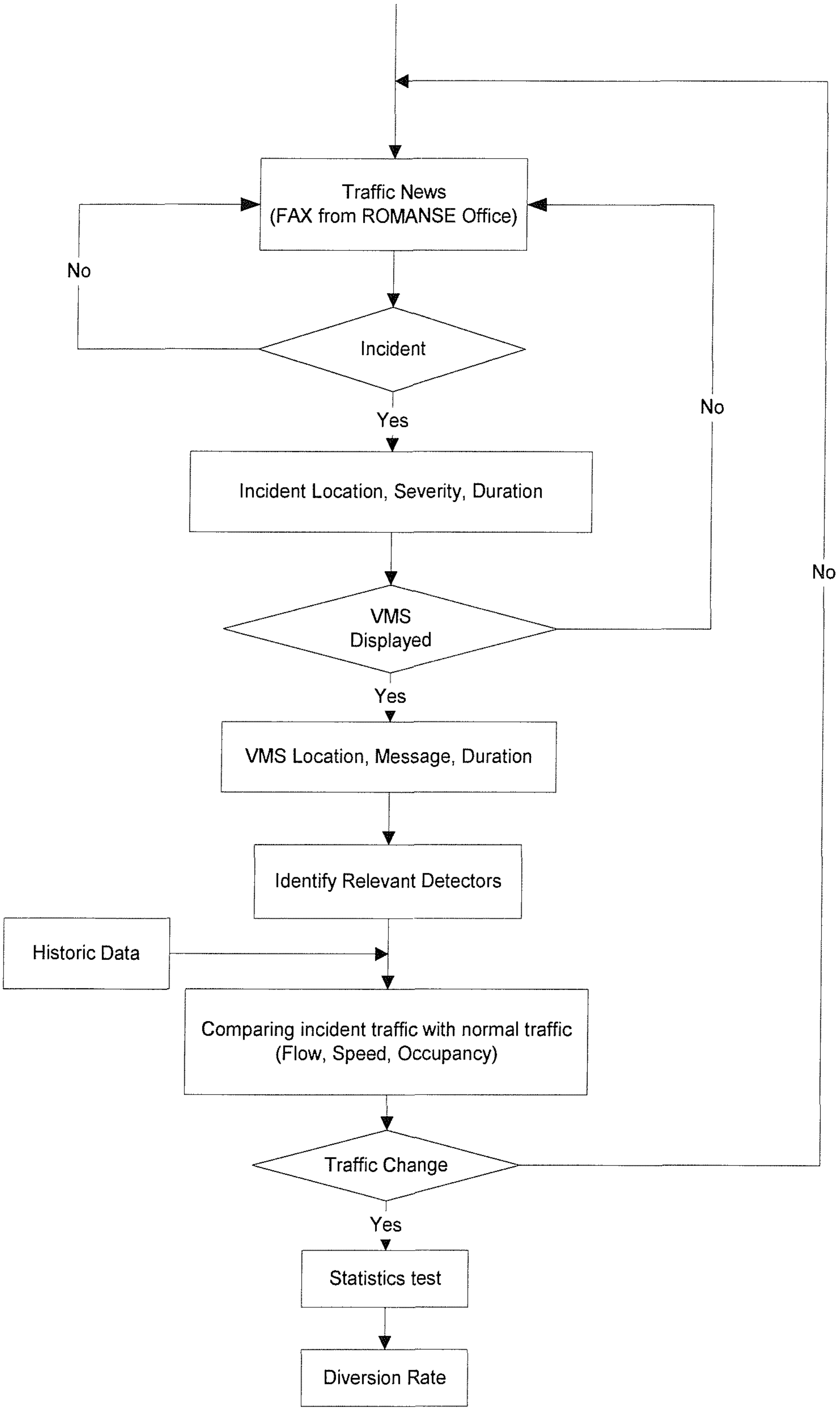

Figure 6.1 Approach to Assess Diversion Effects

6.2 Case studies of incidents on the A35 (inbound)

6.2.1 Site descriptions

The A35 is the main western approach to Southampton which connects the Waterside area with Southampton centre (Figure 6.2). The main road sections of the A35 studied in this research included Totton Bypass (0.7 km), Redbridge Causeway (0.5 km) and Redbridge Road (0.83 km). There are four VMS signs for inbound traffic which are located on Marchwood By-pass (H01), Hunters Hill (H02), Ringwood Road (H03) and Totton By-pass (H07) as shown in Figure 6.2.

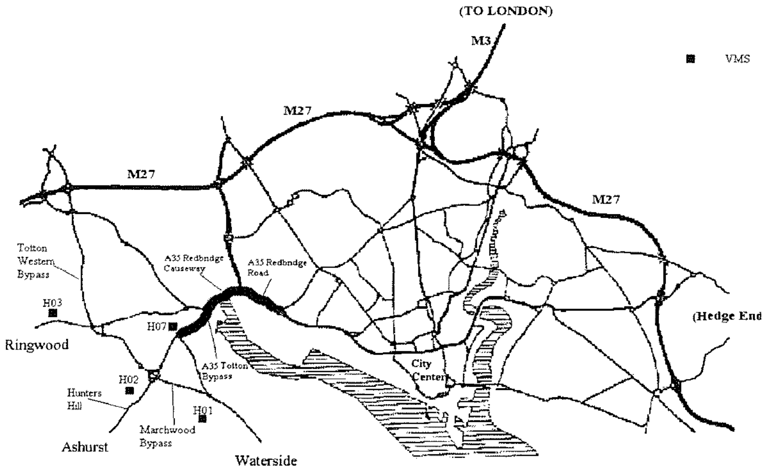

Figure 6.2 A35 in Southampton

During the study period from 01/08/1999 to 20/12/2000, 31 incidents were reported on the A35. Of these incidents, 84% occurred on weekdays, 68% of incidents involved inbound traffic, and 26% outbound traffic (Table 6.1). Classified by causes, accidents, roadworks and broken-down vehicles accounted for 55%, 23% and 19% respectively. Of the incidents, 19% occurred in the AM peak of 07:00-09:00, and 37% in the PM peak of 16:00-18:00 (Table 6.2).

Table 6.1 Incidents by cause on the A35

	Accident	Roadworks	Broken down Vehicles	Other	Total
Inbound	11	3	6	1	21 (68%)
Outbound	4	4	0	0	8 (26%)
Both Direction	2	0	0	0	2 (6%)
Total	17 (55%)	7 (23%)	6 (19%)	1 (3%)	

Table 6.2 Incidents by time distribution on the A35

	Accident	Roadworks	Broken down Vehicles	Other	Total
AM Peak (0700-0900)	2	1	2	0	5 (19%)
PM Peak (1600-1800)	3	6	1	0	10 (37%)
Non-Peak	9	0	2	1	12 (44%)
Total	14 (52%)	7 (26%)	5 (18%)	1 (4%)	

6.2.2 Roadworks on Redbridge Causeway (27/03/00)

6.2.2.1 Location of the incident, VMS and detectors

(i) Incident location

Emergency repair work to the gas mains occurred on Redbridge Causeway which started at 13:00 on Sunday afternoon March 26, 2000 and ended at 17:35 on Monday March 27, 2000. Redbridge Causeway is a dual carriageway with a saturation flow of 4000 vehicles per hour in each direction. The normal eastbound traffic is about 3600 vehicles per hour during the AM peak from 07:00 to 09:30. During the incident, one of the two lanes was closed which resulted in serious congestion on the A35 inbound, especially during the peak hours on Monday March 27. Because of it being an emergency, drivers had no pre-notification.

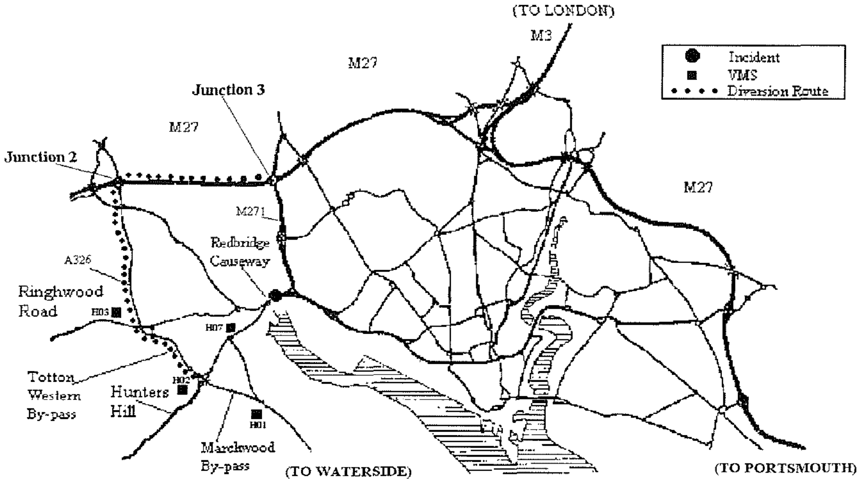

Figure 6.3 Incident location and diversion route

(ii) VMS sites and messages displayed

As illustrated in Figure 6.4, three VMS signs are relevant to this scenario: H01, H02 and H03. (VMS H07 is located too close to the incident and therefore any vehicles passing this VMS location will not be able to divert). During the incident on 27/03/00, the following messages were displayed on all these three signs as shown in Table 6.3:

Table 6.3 VMS messages displayed

Strategy Code	Message	Duration
ASTR 84142	ROADWORKS REDBRIDGE CAUSEWAY DELAYS	07:00-07:36
ASTR 84143	ROADWORKS REDBRIDGE CAUSEWAY LONG DELAYS	07:36-11:12
ASTR 84142	ROADWORKS REDBRIDGE CAUSEWAY DELAYS	11:12-11:41
ASTR 84141	ROADWORKS REDBRIDGE CAUSEWAY SHORT DELAYS	11:41-17:00
ASTR 84142	ROADWORKS REDBRIDGE CAUSEWAY DELAYS	17:00-17:35
ASTR 84114	NO REPORTED INCIDENT	17:35-

(iii) Detector Sites

Traffic data relevant to this incident case were collected from 9 detectors in the vicinity of the incident. The most relevant 7 detector sites are shown in Figure 6.4, including: N350013 (A35 Redbridge Causeway), N14131A&B (A35 Main Road), N14111A&B (A326 Marchwood Bypass northbound), D14112 (ramp road linking March wood Bypass and A35), N14141A (Ringwood Road West), N14141B (Ringwood Road East), N14141C (A326 Totton Western Bypass), N14151A&B (A326).

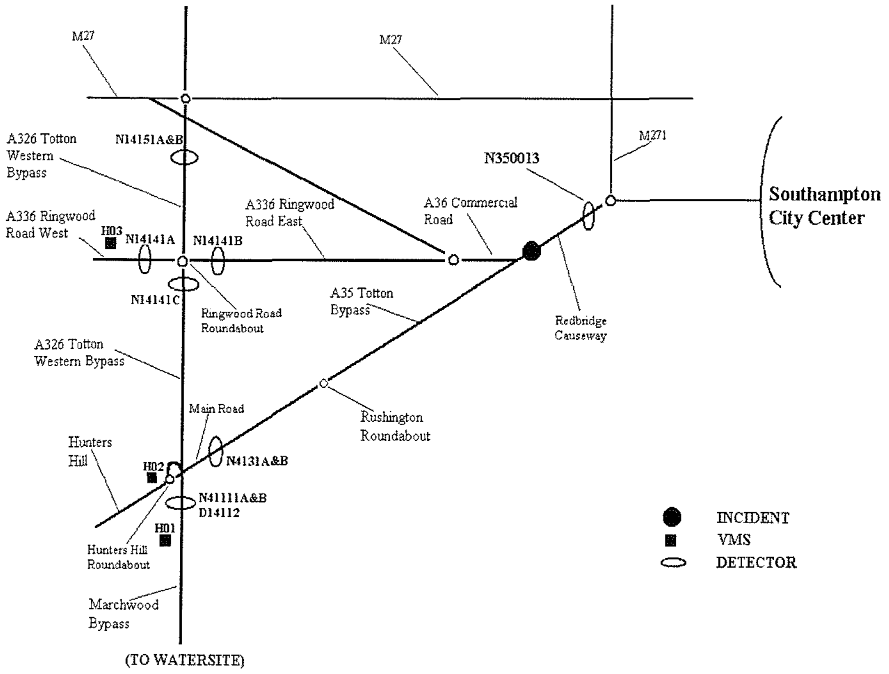

Figure 6.4 Relevant detector sites

The incident occurred on a weekday. Therefore the base traffic flow data, with which to compare the traffic flows on the day of the incident, was taken to be weekdays between 20/03/2000 to 31/03/2000, i.e. one week before and one week after the incident.

6.2.2.2 Results of data analysis

According to detector data (N350013), the eastbound traffic over Redbridge Causeway reduced by 23.8% in the time interval 07:00-19:00 on Mar 27, from 28505 vehicles to 21732 vehicles. The results in Figure 6.5 clearly show that traffic flow on Redbridge Causeway was at its reduced capacity (approximately 2000 veh/h) from 07:00 to 18:00. On Totton Western Bypass, (the only main diversion route available when an incident occurs on Redbridge Causeway), traffic increased by 47.7%, from 6262 vehicles to 9251 vehicles (Figure 6.6). It can be seen that the traffic increase on Totton Western Bypass was not equivalent to the traffic reduction on Redbridge Causeway, i.e. some drivers probably diverted early, and could not be monitored. Traffic flows on both incident and diversion routes during the period of 07:00-09:30, 07:00-12:00, 07:00-19:00 and 00:00-24:00 are listed in Table 6.4.

Table 6.4 Traffic Flow on Incident Route and Diversion Route

	0000-2400	0700-1900	0700-1200	0700-0930
Traffic Passing Redbridge Causeway (Eastbound) N350013				
Normal	34917	28505	13737	8464
Incident	27787	21732	9230	4867
Traffic Reduction	7130	6773	4507	3597
Traffic Passing A326 to M27 (Jct2) N14151A&B				
Normal	7382	6264	2856	2065
Incident	10631	9251	5207	3101
Traffic Increase	3249	2987	2351	1036

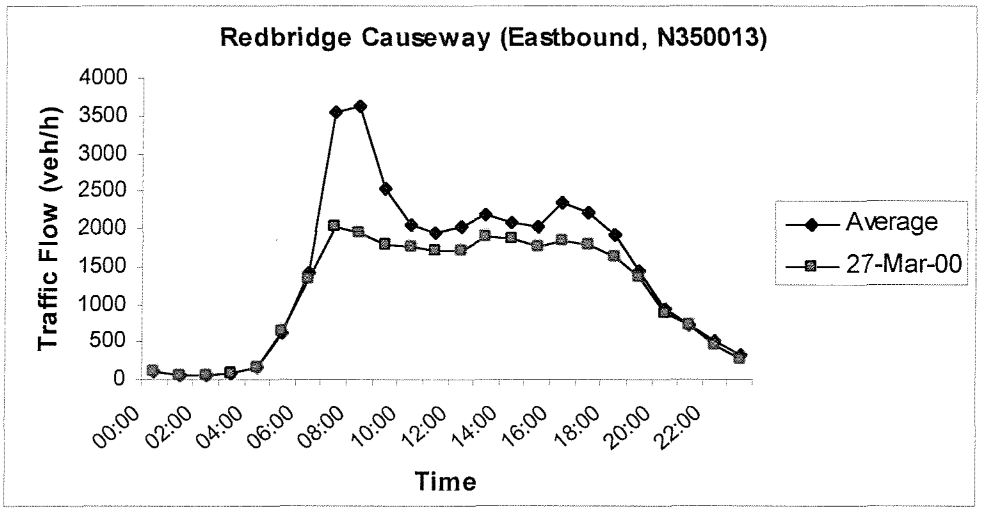

Figure 6.5 Traffic on the A35 Redbridge Causeway

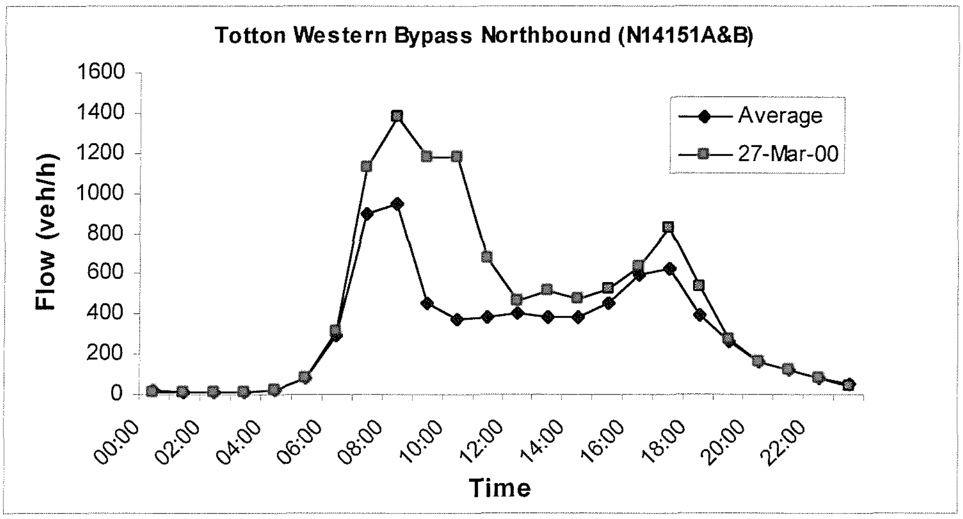

Figure 6.6 Traffic on the A326 Totoon Western Bypass

(i) Diversions at VMS

There were two key decision points for those drivers wishing to avoid the congestion on the incident route: one was at Hunters Hill roundabout (for those drivers passing VMS H01 and H02) to decide whether to stay on their original route of A35 or to divert to A326 Totton Western By-pass; the other was at Ringwood Roundabout (for those drivers passing VMS H03) to decide whether to stay on their original route of A336 Ringwood Road or to divert to A326 Totton Western By-pass. Detector results indicated that driver's diversion rates varied at the VMS locations.

- At the decision point of Hunters Hill Roundabout

For those drivers passing H01 or H02, the A326 Totton Western By-pass was the only diversionary route to avoid the congestion on Redbridge causeway. Therefore, Hunters Hill Roundabout is the decision point for drivers to stay on their usual route of the A35 or to divert to the A326 Totton Western Bypass. According to the detector data from N14141C (Figure 6.7), traffic on Totton Western By-pass increased by 29.5% during the period from 07:00 to 19:00, i.e. 2222 drivers diverted at that diversion point to avoid the congestion on the A35 (incident route).

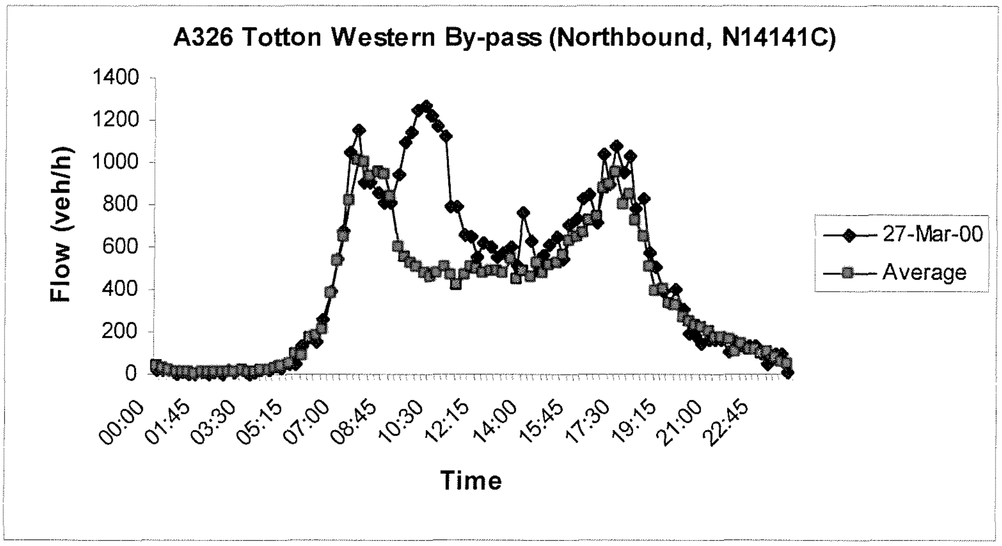

Figure 6.7 Traffic on the A326 Totton Western By-pass northbound

- At the decision point of Ringwood Road Roundabout

From Figure 6.8, which shows the traffic passing Ringwood Road East (N14141B), it can be seen that there was some traffic increase instead of traffic reduction on Ringwood Road East. Such a traffic increase could be the result of:

a) Some drivers made early diversion before VMS H01/H02 to Ringwood Road West (through minor roads not displayed in Figure 6.2), and continued their journey on Ringwood Road East after passing Ringwood Road roundabout.

b) Some drivers from A326 Totton Western Bypass (passing VMS H01/H02) diverted to Ringwood Road East at Ringwood Roundabout.

c) Some mix between situations a) and b).

A comparison of the detector results between N14141B and N14141A, indicated that the traffic profiles on Ringwood Road were consistent before and after Ringwood Roundabout (Figure 6.9). Therefore, it was possible that those drivers passing VMS H03 did not divert to the A326 Totton Western Bypass, including those drivers diverted to Ringwood Road West (made early diversion before). However, it is difficult to justify this assumption by detector data alone.

One of the most likely reasons for driver's not diverting to Totton Western Bypass was the short distance and less congestion on the A336 Ringwood Road East. In normal traffic conditions, the average traffic flow on the A336 Ringwood Road East is less than 550 vehicles/h and the flow is only just over half the capacity, even during the AM peak period. Analysis of occupancy data at N14141B suggested there was very little change in speed, which indicated that the queues did not tail back to the 'decision point' of Ringwood Roundabout.

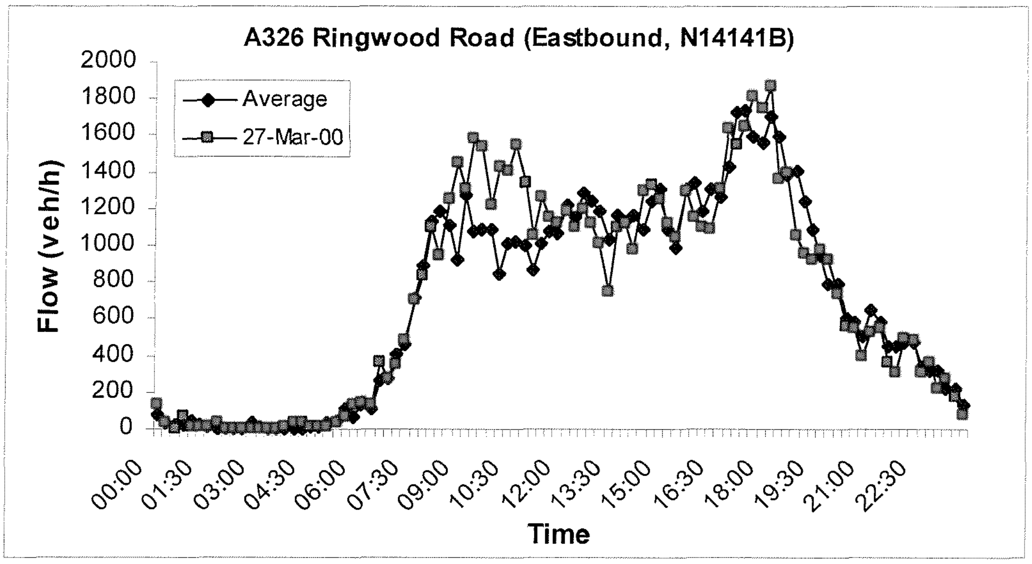

Figure 6.8 Traffic on Ringwood Road at N14141B

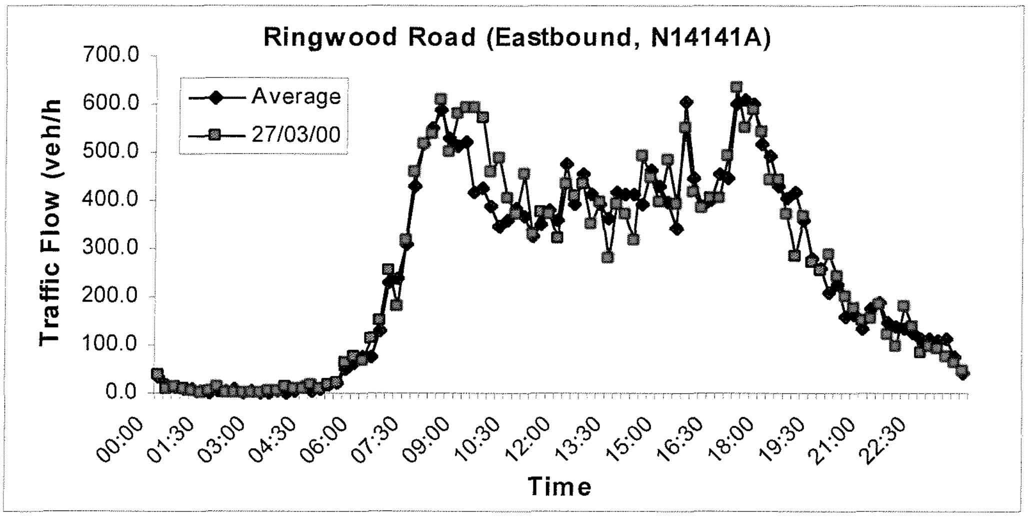

Figure 6.9 Traffic on Ringwood Road at N14141A

(ii) Early and late diversion

For those drivers passing the VMS, their diversion may be conducted with or without the influence of observed queues. In this research, drivers who diverted before having encountered the queues caused by the incident are defined as early diversions; and drivers who diverted after having encountered the queues are defined as late diversions.

At VMS H01 and H02, a message specifying "Long Delays" was sent out when the queues stretched back to Rushington roundabout which was 1.27km from the 'decision point' of Hunters Hill Roundabout. Otherwise, "Short Delays" or "Delays" messages were sent out. It was impossible for drivers to observe the queues at the Hunters Hill Roundabout if the queues ended before Rushington roundabout. Therefore, those diversions during the display of 'Short Delays' and 'Delays' were of early diversions; and those during the display of 'Long Delays' were of late diversion.

To illustrate the relationship between VMS message and diversion rates, the route choice of those drivers passing VMS H01 was taken as an example. For those drivers heading to central Southampton and passing VMS H01, Hunters Hill roundabout was the 'decision point' to decide whether to continue to use their usual route of the A35 or to divert to the A326 Totton Western Bypass. The results shown in Figure 6.10 give the flows on the A326 Totton Western Bypas northbound (N14111A&B). It can be seen that there was a significant difference in the number of drivers who diverted to A326 Totton Western Bypass at different stages of the incident.

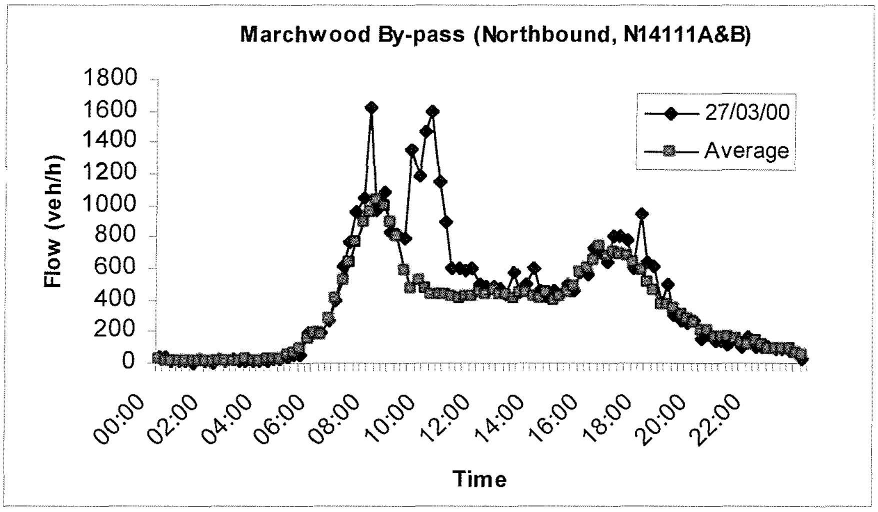

Figure 6.10 Traffic on Marchwood Bypass Northbound

Analysis of detector data showed that 7% of drivers diverted when the message "Short Delays" was displayed (Table 6.5); 18-34% of drivers diverted when the message "Delays" was displayed, and 64% of drivers diverted when the message "Long Delays" was displayed on the VMS. It can be seen that diversion rates increased as the strength of the message increased, which illustrated the strong impacts of VMS information on drivers' routing behaviour.

Table 6.5 Diversion rate and VMS messages displayed

	07:00-07:30	07:30-11:15	11:15-11:45	11:45-17:00	17:00-17:30
	"Delays"	"Long Delays"	"Delays"	"Short Delays"	"Delays"
Normal Traffic (D14112)	450	2439	253	2676	264
Incident Traffic (N14111A&B)	+79	+1556	+86	+184	+52
Diversion Rate (%)	0.18	0.64	0.34	0.07	0.20
T-test results	t=7.611, $t_{\alpha/2}$=2.3646, df=7, α=5%	t=31.180, $t_{\alpha/2}$=2.3646, df=7, α=5%	t=13.072, $t_{\alpha/2}$=2.3646, df=7, α=5%	t=3.605, $t_{\alpha/2}$=2.3646, df=7, α=5%	t=10.370, $t_{\alpha/2}$=2.3646, df=7, α=5%

Speed and occupancy data were collected from the SCOOT detectors, in addition to flows. The detectors on the A35 (N14131A&B) showed an average percentage of occupancy of 50-70% in the time interval 07:30-10:30 during the incident. The typical values for the same time intervals in normal conditions are only 5%, although there is a peak of about 15% between 07:45 and 09:00. Corresponding data from the detector on Marchwood Bypass (N14111A&B) showed that the average occupancy during the incident increased from the usual 5% to 50-60%. The occupancy shown in Figure 6.11 illustrates that the queues tailed back to the A35 junction with Chapel Lane (0.1km from the 'decision point' of Hunters Hill Roundabout) at about 07:40 AM.

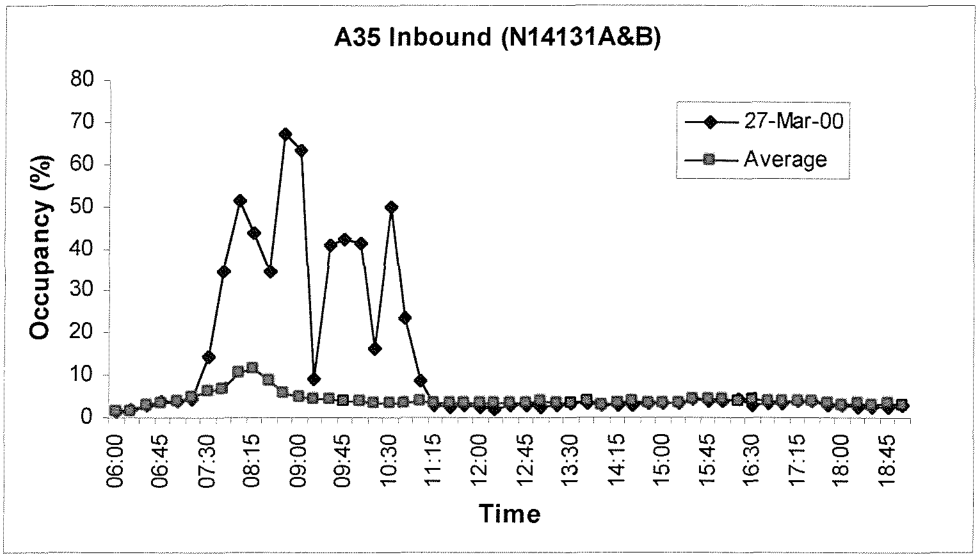

Figure 6.11 Occupancy on the A35 junction with Chapel Road

Speed data from the two detector sites (N14131A&B, N14111A&B) were analysed in a similar way. The average traffic speed on the incident route reduced from the usual 60 – 70 km/h to only 10 km/h during the morning peak. The speed on the diversion route also reduced from the usual 70 km/h to 10 km/h. Interestingly, there was a time lag of about 15 minutes in this speed reduction between the incident route and diversion route, as can be seen in Figure 6.12.

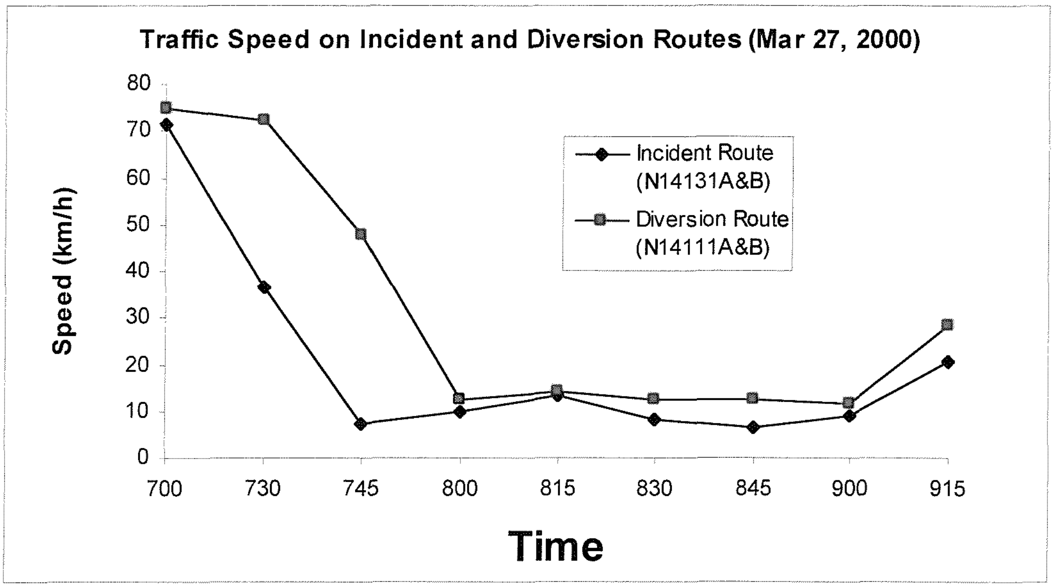

Figure 6.12 Speed on the A35 (N14131A&B) and the A326 (N14111A&B)

6.2.2.3 Discussion

(i) About the messages displayed

"Short Delays", "Delays" and "Long Delays" were the three main messages displayed. These messages may have been too vague for drivers to understand. For example, the "Long Delays" could mean a queue length of 518 vehicles (to Rushington roundabout) or a queue length of 805 vehicles (to the decision point of Hunters Hill roundabout). It was not clear how drivers perceived the difference between these three messages regarding status of congestion on the incident route. The provision of quantitative information may have been more helpful for drivers to make a better route choice decision at the right time for the conditions.

(ii) About the incident severity

A 50% reduction in capacity on Redbridge Causeway had different impacts on the two merging roads: the A35 Totton By-pass and the A36 Commercial Road (Figure 6.4). The A35 Totton By-pass is a major road with two lanes, whilst the A36 is a minor road with one lane giving way to the A35. In normal traffic conditions, the capacity of the A35 is about twice that of the A36 Commercial Road. However, a 50% reduction in capacity on Redbridge Causeway does not mean there was similar reduction in capacity on the A35 Totton By-pass and the A36 Commercial road. According to videos taken during the incident, when there were queues on both the A35 Totton By-pass and A36 Commercial Road during the incident, vehicles joined the Redbridge Causeway in turn from the A35 and the A36. Thus, there was greater reduction in capacity on the A35 Totton by-pass than that on the A36 Commercial Road. According to the detector flows, 1946 vehicles passed through the incident link per hour during the AM peak. Assuming this traffic was split evenly between the two merging roads, only 973 vehicles could join from each road, which led to a capacity reduction of 67.6% on the A35 Totton By-pass (compared with the normal saturation flow of 3000 veh/h), and a reduction of 35% on the A36 Commercial Road.

(iii) About the missing traffic

Only 2987 vehicles were recorded on the main diversion route of Totton Western Bypass (N14151A&B). There was a difference of 3786 vehicles between incident route (N350013) and diversion route (N14151A&B). The most likely reason for this is that some drivers re-routed and joined the A326 at a point north of detectors N14151A&B and therefore escaped detection. In addition, it was also possible that some drivers re-routed to the M27 via Junction 1. Unfortunately, as there was no network monitoring facilities on the M27 at the time of this incident, it is not possible to verify this explanation. The accuracy of the detector on Redbridge Causeway has been investigated by comparing footage from nearby CCTV cameras to manually assess the flows in both incident and normal traffic conditions.

6.2.3 Results from other incident cases on Redbridge Causeway

All the weekday incidents on the A35 involving inbound traffic were investigated. Of them, nine incidents on Redbridge Causeway which caused serious congestion were studied in detail. The main results from the 9 incident cases are summarised in Table 6.8.

(i) Incidents on Redbridge Causeway

All the 9 incidents (one Brokendown, one Roadwork and seven Road Traffic Accident) occurred with the same level of severity, i.e. one lane blocked. However, their duration were different, from 0.4 hour (RTA on 25/04/00) to 10.5 hours (Roadworks on 27/03/00).

(ii) Diversion and messages displayed

"Short Delays", "Delays" and "Long Delays" were the three main types of VMS messages used to describe congestion levels. The message "Short Delays" was displayed in four incidents (Brokendown on 21/09/99, Roadworks on 27/03/00, RTA on 25/04/00 and 24/11/00). However, only in the incident of Roadworks on 27/03/00 was diversion found, in which 7% drivers diverted. The message of "Delays" was displayed in six incidents (Brokendown on 21/09/99, Roadworks on 27/03/00, RTA on 25/04/00, 05/09/00, 03/10/00, 08/11/00 and 20/11/00), 7.6 -14.6% of drivers diverted which varied with incident causes, time of incidents and duration. The message of "Long Delays" was displayed in five incidents (Roadworks on 27/03/00, RTA on 27/03/00, 05/09/00, 03/10/00 and 20/11/00), 24-64% of drivers diverted which varied with incident causes, time of incidents and duration. The results in Table 6.6 indicated that diversion rates increase as the strength of VMS message increase.

Table 6.6 Diversion rates and messages displayed

	"Short Delays"	"Delays"	"Long Delays"
Diversion Rate	0-7%	8.1-14.6%	24-64%

(iii) Early and late diversion

For the incident cases suitable for comparisons, it can be found that the late diversion rates were higher than the corresponding early diversion rates. On average, the early diversion rate was 12.6% (with the message "Delays"), compared with 35.8% for late diversion. This illustrated that drivers were more likely to divert after obtaining visual confirmation of the observed queues caused by the incidents. However, it is not clear how much the VMS contributed to these late diversion because the lack of data available to compare diversion before and after VMS installation

(iv) Diversion and VMS locations

Although the three VMS signs of H01, H02 and H03 were operated using the same strategies, the diversion rates varied according to VMS sites. Significant diversions have been found at VMS H01 and H02 in the incident cases studied, but very little diversion has been found at VMS H03. One possible reason for drivers' reluctance to divert at VMS H03 was that they had less experience of congestion on Ringwood Road East when similar incidents occurred. The results in Table 6.7 show the comparisons of the normal traffic between the A35 Totton Bypass and the A336 Ringwood Road East (downstream roads of the VMS H03). It can be seen that traffic demand on the A336 Ringwood Road East is much lower than that on the A35 Totton Bypass. Analysis of detector data indicated that for the nine incidents occurring on Redbridge Causeway, no queues stretched back to N14141B during the incidents studied.

Even at the same VMS site (H01 and H02) near the decision point of Hunters Hill roundabout, different diversion rates were found at different VMS locations. More drivers passing VMS H01 diverted to Totton Western Bypass than those passing VMS H02. One likely reason was that it was more difficult for those passing VMS H02 to divert to Totton Western Bypass than for those passing VMS H01, as those drivers passing H02 had to access to Totton Western Bypass by give way, whilst those passing H01 had priority to access to Totton Western Bypass.

Table 6.7 Saturation flows on downstream road of decision points

Decision Point	VMS H01	VMS H02	VMS H03
	Hunters Hill Roundabout	Hunters Hill Roundabout	Ringwood Roundabout
Down Stream Road of the Decision Point	A35 Main Road	A35 Main Road	A336 Rinwood Road
Saturation Flow (veh/h)	3000	3000	1000
Normal AM Peak Flow (veh/h)	1450	1450	550

Table 6.8 Information and results from other incident cases on the A35

Date	Incident					VMS		Diversion	
	Location	Direction	Type	Severity	Duration	Message	Duration	Early (D14112) (N14111A&B)	Late (D14112) (N14111A&B)
21/09/99	Redbridge Causeway	Inbound	Brokendown	One lane blocked	1630-1730	84181 84182 84181 84114	1630-1700 1700-1701 1701-1740 1740-	0	N/A
27/03/00	Redbridge Causeway	Inbound	RTA	One lane blocked	1748-1826	84123 84128 84123 84114	1748-1758 1858-1805 1805-1835 1835-	N/A	24.0% (17:48-18:35)
27/03/00	Redbridge Causeway	Inbound	Roadworks	One lane blocked	0700-1735	84142 84143 84142 84141 84142 84144	0700-0736 0736-1112 1112-1141 1141-1700 1700-1735	18% (0700-0730) 34% (11:15-11:45) 7% (11:45-17:00) 20% (17:00-17:30)	64% (07:30-11:15)
25/04/00	Redbridge Causeway	Inbound	RTA	One lane blocked	1700-1724	84122 84121 84114	1700-1724 1724-1728 1728-	10% (17:00-17:28)	N/A
05/09/00	Redbridge Causeway	Inbound	RTA	One lane blocked	0937-1034	84122 84123 84114	0937-0954 0954-1100 1100-	7.6% (09:37-09:54)	25.0% (09:54-11:00)
03/10/00	Redbridge Causeway	Inbound	RTA	One lane blocked	1455-1606	84122 84123 84127 84114	1455-1524 1524-1606 1606-1635 1635-	9.7% (14:55-15:24)	33.2% (15:24-16:06)

(Continued)

Date	Incident					VMS		Diversion	
	Location	Direction	Type	Severity	Duration	Message	Duration	Early (D14112) (N14111A&B)	Late (D14112) (N14111A&B)
08/11/00	Redbridge Causeway	Inbound	RTA	One lane blocked	1338-1402	84122 84114	1338-1402 1402-	9.6% (13:38-14:02)	N/A
20/11/00	Redbridge Causeway	Inbound	RTA	One lane blocked	0750-0920	84122 84123 84114	0750-0800 0800-0920 0920-	No Data	33.0% (08:00-09:20)
24/11/00	Redbridge Causeway	Inbound	RTA	One lane blocked	1531-1628	84121 84114	1531-1628 1628-	0%	N/A

6.3 Case studies of incidents on the A3024 (inbound)

6.3.1 Site descriptions

The A3024 is a main eastern approach to Southampton which connects central Southampton with the Hedge End area (Figure 6.13). The main road sections studied include Northam Road (1.3km), Bitterne Road West (1.4km) and Bursledon Road (2.9km). During the study period from August 1999 to December 2000, there were 28 incidents of non-roadworks and 28 incidents of roadwork projects (involving in 246 roadwork days). Of the incidents, 91.1% occurred on Bitterne Road West and Northam Road.

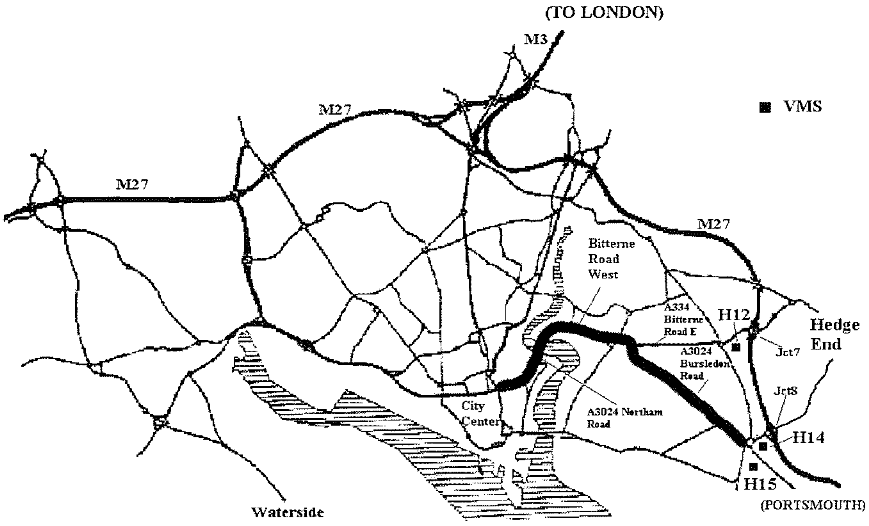

Figure 6.13 The A3024 in Southampton

For inbound traffic from the Hedge End area to central Southampton, there are three relevant VMS locations: H14 (A3024 between Bursledon roundabout and M27 jct8), H15 (A27 Bursledon Road) and H12 (A334 Between Thornhill roundabout and M27 jct7).

6.3.2 Roadworks on Northam Road inbound (28/11/2000)

6.3.2.1 Incident location and traffic monitoring

(i) Incident site

The roadworks occurred at the A3024 Northam Road junction with Britannia Road which is about 1.4 km from central Southampton and 4.9 km from VMS locations H14 and H15. Northam Road is a single carriageway with two lanes and a saturation flow of 3000 vehicles per hour in each direction. The usual inbound and outbound flows on the incident link are 1950 veh/h and 760 veh/h respectively (AM peak). The roadworks started at 07:00 in the morning of Nov 28, and ended at 19:00 in the evening November 30, 2000. During the incident, four-way temporary signals were in operation on Northam Road junction with Britainnia Road which resulted in severe congestion, especially during peak periods on Northam Road inbound.

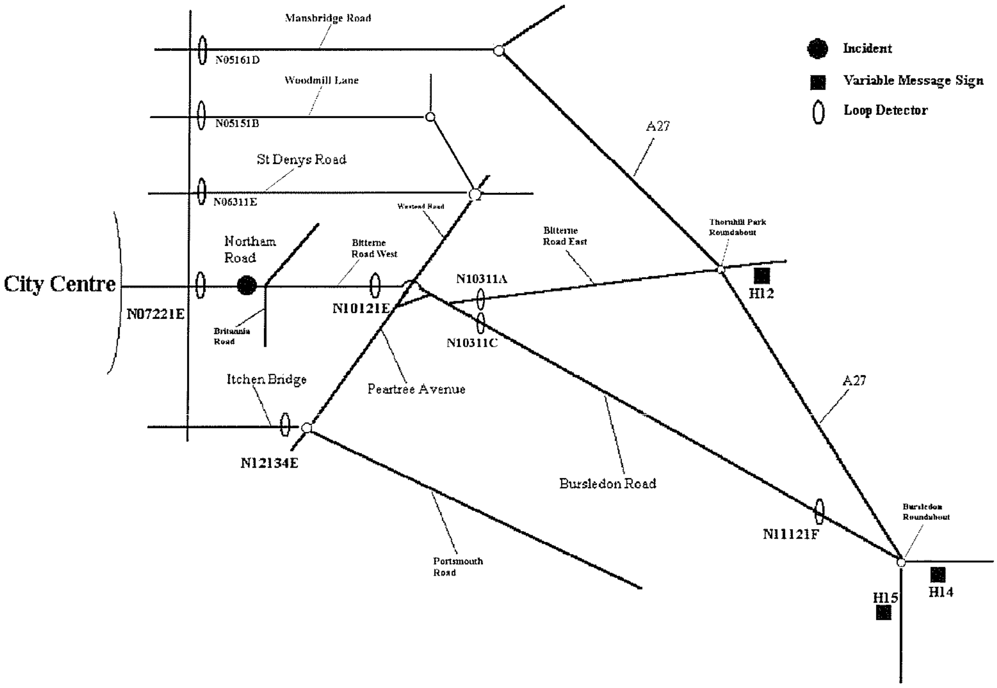

Figure 6.14 Detectors on Bursledon Road

(ii) Messages displayed

During the incident, VMS H12, H14 and H15 displayed the following messages as shown in Table 6.9:

Table 6.9 Messages displayed

Strategy Code	Message	Duration
ASTR 79141	ROADWORKS NORTHAM ROAD SHORT DELAYS	07:00-07:17
ASTR 79142	ROADWORKS NORTHAM ROAD DELAYS	07:17-07:50
ASTR 79143	ROADWORKS NORTHAM ROAD LONG DELAYS	07:50-10:40
ASTR 79142	ROADWORKS NORTHAM ROAD DELAYS	10:40-1150
ASTR 79141	ROADWORKS NORTHAM ROAD SHORT DELAYS	11:50-15:34
ASTR 79142	ROADWORKS NORTHAM ROAD DELAYS	15:34-18:58
ASTR 111	BLANK DOWN SIGN	18:58-

(iii) Alternative routes

As maybe seen from Figure 6.13, when the incident occurred on Northam Road inbound, there were several alternative routes for those drivers heading to Central Southampton to avoid the incident.

For those passing VMS H12, the main alternative routes were:

- A27 (westbound) – Mansbridge Road (westbound);
- Bitterne Road East (westbound) - Westend Road (northbound) – St Denys Road (westbound);
- Bitterne Road East (westbound) - Westend Road (northbound) – Woodmill Lane (westbound);
- Bitterne Road East (westbound) - Peartree Avenue (southbound) – Itchen Bridge (westbound).

For those passing the VMS H14 and H15, the main alternative routes were:

- A27 (westbound) – Mansbridge Road (westbound);
- Bursledon Road (westbound) - Westend Road (northbound) – St Denys Road (westbound);
- Bursledon Road (westbound) - Westend Road (northbound) – Woodmill Lane (westbound);
- Bursledon Road (westbound) - Peartree Avenue (southbound) – Itchen Bridge (westbound).

(iv) Traffic monitoring

Data for this case study were collected from 17 detectors in the vicinity of the incident. The seven most relevant detectors are shown in Figure 6.14. These are on Northam Road (N07221C&D), Mansbridge Road (N05161D), Woodmill Lane (N05111B), St Denys Road (N06311E), Itchen Bridge (N12134E), Bitterne Road West (N10121E) and Bursledon Road (N10311C).

The incident occurred on a weekday. Therefore the base traffic flow data, with which to compare the traffic flows on the day of the incident, was taken to be weekdays between the 1st November and 27th November 2000.

6.3.2.2 Results of data analysis

Figure 6.15 shows the traffic passing the incident location on Northam Road. It can be seen that there was a substantial traffic reduction during the incident, especially in AM and PM peak periods. It is believed that this reduction on Northam Road was the results of drivers' diverting to avoid the congestion on the incident route and the bottleneck effects of the roadworks.

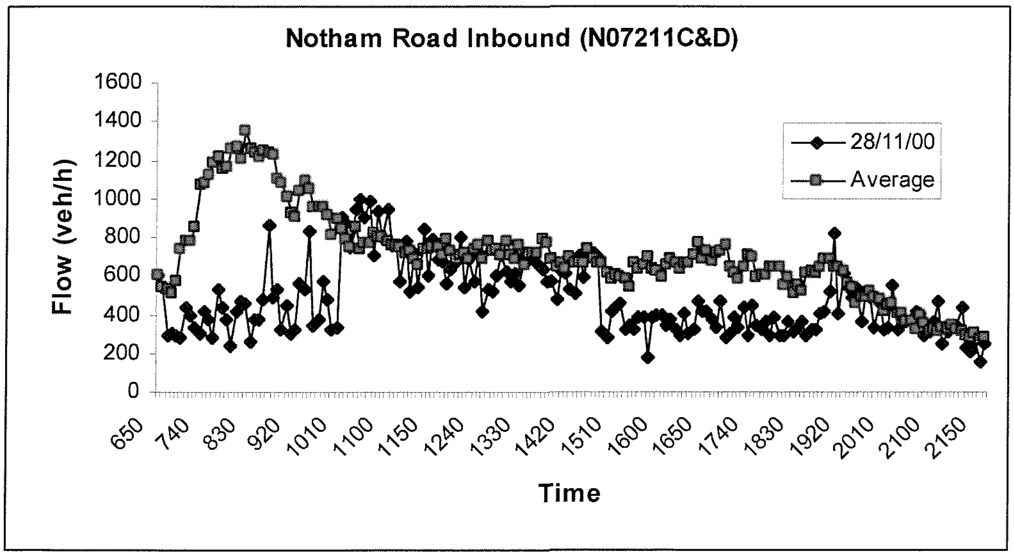

Figure 6.15 Traffic on the A3024 Northam Road inbound

Comparing the observed traffic during VMS display with normal traffic indicates that there were significant increase in traffic (07:00 –12:00 AM) on the diversion routes.

- Traffic on Northam Road (N07221C&D) was less than normal by 39.7%;
- Traffic on the A27 Mansbridge Road westbound (N05161D) was greater than normal by 12.1%;
- Traffic on Woodmill Lane (N05151B) was greater than normal by 15.4%;

- Traffic on the A3035 St Denys Road (N06311E) was greater than normal by 13.0%;

- Traffic on Itchen Bridge (N12134E) was greater than normal by 12.0%.

According to detector data after Bursledon Road junction with Westend Road (N10121E), traffic reduced by 1150 vehicles during the AM peak period of 07:00-09:30, which represented a diversion rate of 42.4% including both early and late diversion (Table 6.10).

Table 6.10 Traffic Passing Bursledon Road junction with Westend Road (N10121E)

	0700-2200	0700-1900	0700-1200	0700-0930
Normal	10266	8919	4738	2710
Incident	7946	6847	3057	1560
Traffic Reduction	2320	2072	1681	1150

(i) At VMS H12

For those drivers passing VMS H12, Thornhill Park Roundabout was the decision point for them to decide whether to divert to the route of the A27-Mansbridge Road westbound (the immediate diversion route at VMS H12) or stay on their original route of Bittern Road East. Figure 6.16 shows the traffic on Bitterne Road East inbound (N10311A). It can be seen that there was a substantial traffic reduction during the incident, especially during the time period of 08:00-10:30 when the traffic level fell by 665 vehicles on Bittern Road East. It is believed that such traffic reduction is the results of drivers' diverting to alternative routes. This was supported by increased traffic on the diversion route of Mansbridge Road as shown in Figure 6.17. During the time period of 08:00-10:30, the traffic increased by 284 vehicles on Mansbridge Road (N05161D). It can be seen that the traffic increase on Mansbridge Road was less than the traffic reduction on Bittern Road East. This was because some drivers diverted using alternative routes other than Mansbridge Road (e.g. through the roads in the residential areas). Because N10311A is the only detector between Thornhill Park Roundabout and the Bitterne Road East junction with Bursledon Road, it is difficult to know how many drivers diverted through which roads.

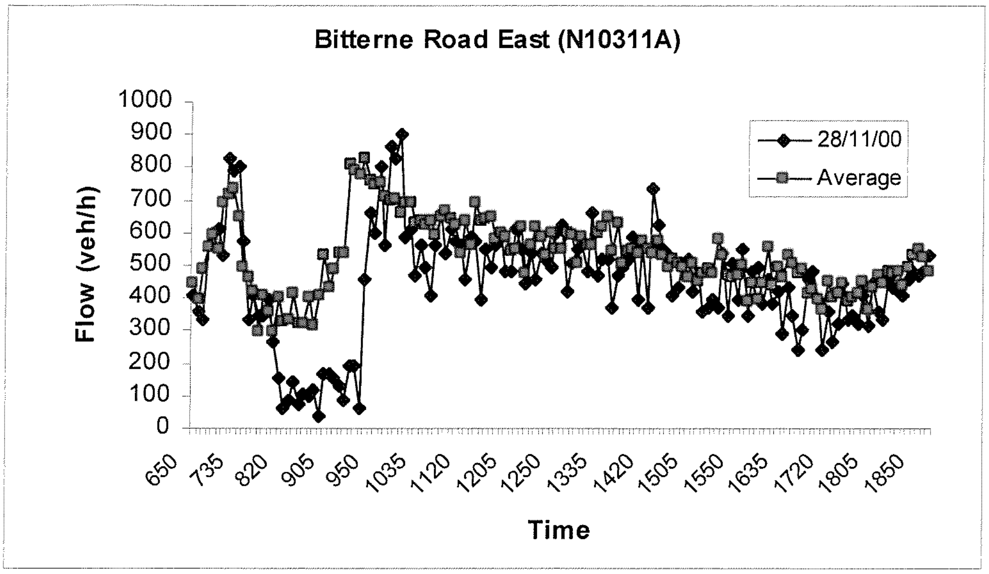

Figure 6.16 Traffic on Bittern Road East (inbound)

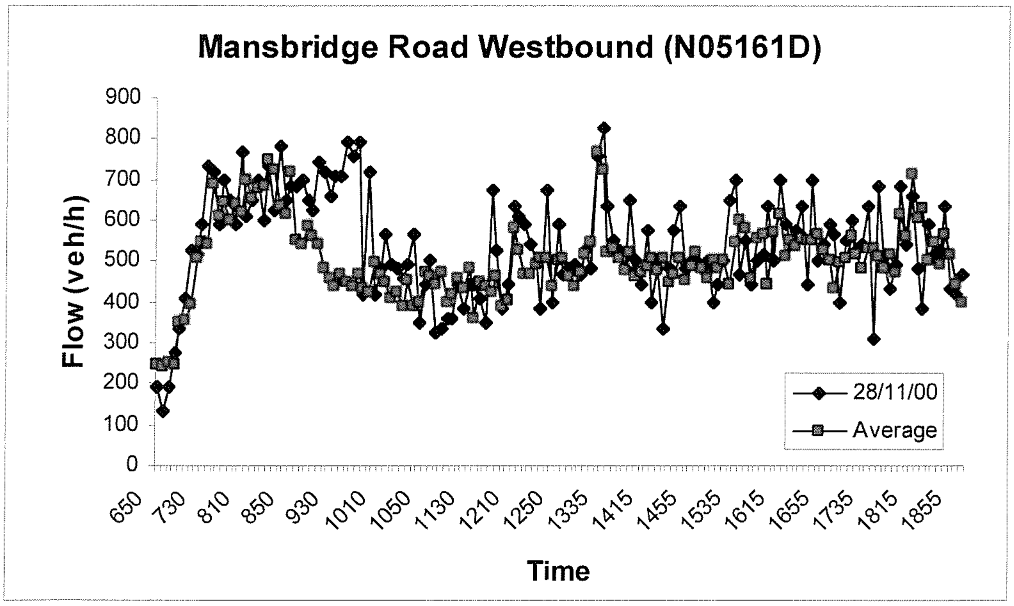

Figure 6.17 Traffic on Mansbridge Road westbound

(ii) At VMS H14 and H15

For those drivers passing VMS H14/H15, Bursledon Roundabout is the first decision point for them to decide whether to divert or not. The route of the A27 westbound - Mansbridge Road westbound was the immediate diversion route at these VMS (i.e. early diversion route). Drivers staying on the route of Bursledon Road westbound could divert later using other diversion routes, e.g. the route of Westend Road (Northbound) - St Denys Road (Westbound)

- Early diversion

On Bursledon Road westbound, the nearest detector to the VMS locations is N11121F, which is about 0.5 km from Bursledon Roundabout. According to traffic data recorded by the detector, traffic reduced by 56 vehicles during the time period 07:50-09:00. This change was statistically significant based on t-test results ($t=5.234$, $t_{\alpha/2}=2.1448$, $df=14$, $\alpha=5\%$). It is believed this traffic reduction was the result of drivers' divertion to the route of A27 westbound – Mansbridge Road. Such traffic diversion was confirmed by the traffic increase on Mansbridge Road (N05161D).

Comparing occupancy data indicated that the queues did not stretch back to the Bursledon Road junction with Bath Road (N10321C), which was 2.5km from the Bursledon Roundabout. Therefore, drivers could not observe the queues when they made diversion at these VMS, and it was believed that the diversion was entirely the result of traffic information.

- Late diversion

Those drivers passing VMS H14/H15 and staying on the route of Bursledon Road could divert at Bursledon Road junction with Westend Road by using the slip road, or by using the roads in the residential areas before reaching Bursledon Road junction with Westent Road. According to detector data (N10121E), during the time period of 07:00-12:00 AM traffic on the incident route fell by 1681 vehicles. It is believed that this traffic reduction is the result of drivers' diversion, which is supported by the traffic increase on the alternative routes as shown in Table 6.11.

Table 6.11 Traffic changes on diversion routes (07:00-12:00AM)

	St Denys Road (N6331E)	Itchen Bridge (N12134E)	Woodmill Lane (N05111B)
Traffic Change (veh)	+630	+139	+334
Increase (%)	13.0	12.0	15.4

There are nine junctions (with detectors) on Bursledon Road between Bursledon Roundabout and Bursledon Road junction with Westend Road. Figure 6.18 and Table 6.12 show the location of the detectors and the traffic passing these detectors. By tracing the traffic data along the Bursledon Road, a sudden traffic reduction of 650 vehicles was found at the detector site N10311, which indicated that vehicles diverted by using junction G (there is a minor road connecting junction G with Bittern Road East was not listed in Figure 6.18).

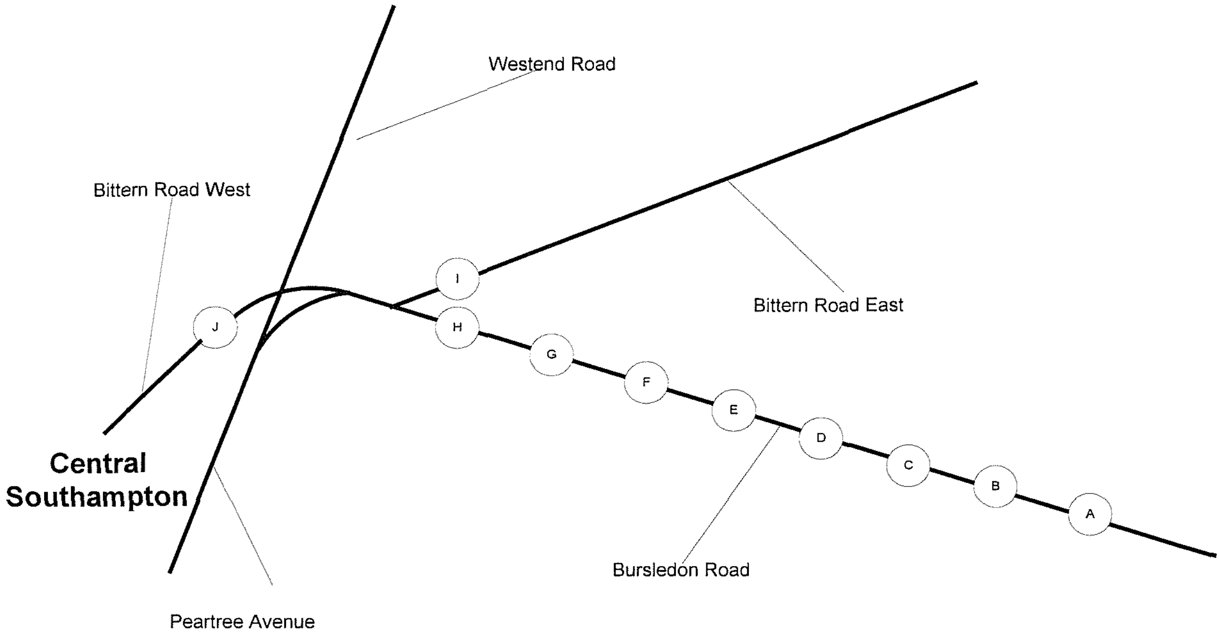

Figure 6.18 Detectors on Bursledon Road westbound

Table 6.12 Traffic change along the Bursledon Road during the period of 07:00-12:00

Detector	A N11121F	B N11111Z	C N10361A	D N10351D	E N10341E
Traffic Change	-133	-160	-51	-132	-139
Detector	F N10331D	G N10321C	H N10311C	I N10311A	J N10121E
Traffic Change	-186	-106	-754	-665	-1681

It is believed that such late diversion was made after drivers had encountered the queues on the incident route. This was supported by the occupancy data from detector N10121E (Figure 6.19). During the time period from 08:10 to 10:40, the occupancy increased significantly which indicated that the queues stretched back to Bursledon Road junction with Westend Road.

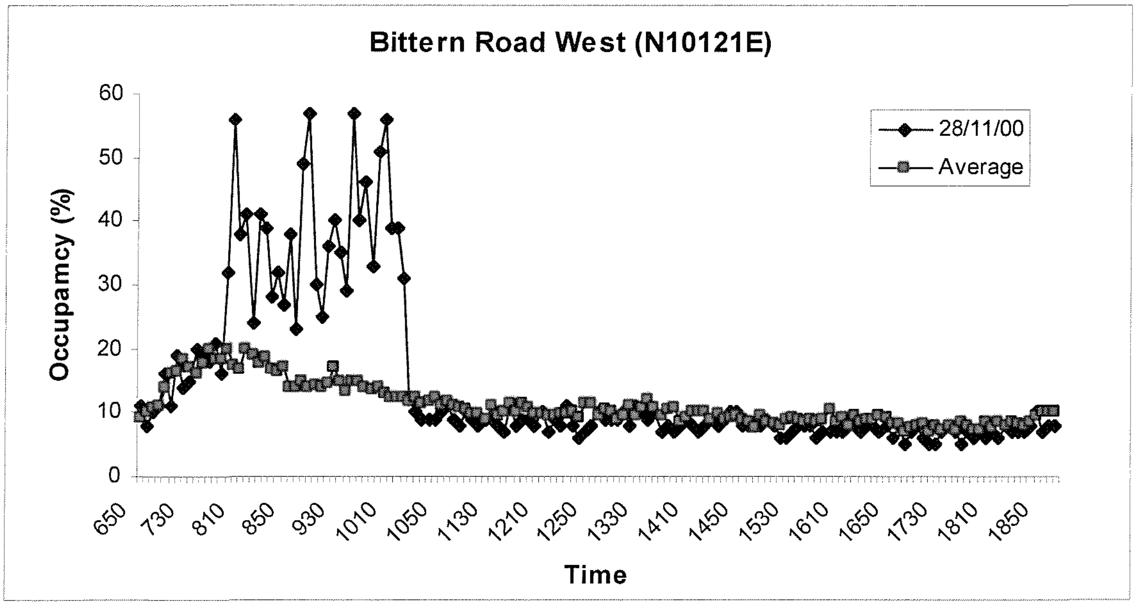

Figure 6.19 Occupancy on the A3024 Bittern Road West (N10121E)

During the time period of 07:00-12:00, 1103 vehicles diverted at locations near the Bursledon Road junction with Westend Road, which represent a diversion rate of 42.4%%. This high proportion of diversions indicated that drivers were more likely to divert once they had received visual confirmation of the queues. However, because no data was available to compare traffic change between before and after VMS implementation, it is not clear how much the VMS itself contributed to such late diversion.

(iii) Diversion and messages displayed

Their diversion responses to VMS during AM and PM peak periods for those drivers passing VMS H14 and H15 are illustrated in Table 6.13. It can be seen that the diversion rate increased as the strength of the VMS messages increased. No traffic diverted during the display of the message "Short Delays".

Table 6.13 Traffic passing detector N11121F

	"Short Delays"	"Delays"	"Long Delays"	"Long Delays"
Period	07:00-07:17	07:17-07:50	07:50-09:00	09:00-10:40
Normal traffic (veh)	118	477	961	1133
Incident traffic (veh)	121	451	905	1100
Traffic reduction	--	5.4% (t=3.712, $t_{\alpha/2}$=2.1604, α=5%, df=13)	5.8% (t=5.234, $t_{\alpha/2}$=2.1448, α=5%, df=14)	2.9% (t=2.120, $t_{\alpha/2}$=2.1199, α=5%, df=16)

6.3.2.3 Conclusion

Based on the results from this incident case, the following conclusions can be drawn about the drivers' diversion responses to VMS:

- 5.8% of drivers made early diversions to the route of Mansbridge Road at VMS H14/H15. One likely reason for this relatively low level of early diversion was the route of Mansbridge Road (recommended by VMS implicitly), although less congested, was located in the outskirts of Southampton and was 1.9 km longer that the incident route.

- More drivers diverted to the route of Mansbridge Road at VMS H12 than those at VMS H14/H15. During the time period of 07:50-10:40, i.e. during the display of 'Long Delays' message, 12.1% vehicles diverted at VMS H12, compared to the 4.3% vehicles at VMS H14/H15.

- In the AM peak period of 07:00-09:00, no drivers made early diversion during the display of 'Short Delays'; 5.4% (statistically significant) of drivers made early diversion during the display of 'Delays' message, and 5.8% (statistically significant) during the display of 'Long Delays'.

- Drivers' responses to VMS messages were different during different times in the peak. With the 'Long Delays' information, 5.8% of drivers diverted during the time period of 07:50-09:00, whilst 2.9% of drivers diverted during the time period of 09:00-10:40, which was statistically insignificant.

6.3.3 Results from other incident cases

Of the 56 incidents occurring on the A3024, 11 cases concerning inbound traffic were analysed in detail. Table 6.15 shows the main results from these incident cases (inbound).

(i) Incidents causes and severity

Of the 11 incidents studied, seven occurred on Bittern Road West (Brokendown on 10/11/99; RTA on 23/09/99 and 01/08/00; Roadworks on 24/08/99, 13/10/99, 15/12/99 and 23/03/00) and four on Northam Road (RTA on 03/10/00, Shed Load on 20/11/00, Roadworks on 16/06/00 and 28/11/00). All of these incidents occurred with the severity of "one of the two lanes blocked", except the one on 01/08/00, in which the RTA resulted in Bittern Road West being closed during the incident.

(ii) VMS messages and diversion

The message of "Short Delays" was displayed during six incidents (RTA on 01/08/00, Roadworks on 24/08/99, 15/12/99, 23/03/00, 16/06/00 and 28/11/00). No diversion was found to have taken place during the showing of this message. "Delays" and "Long Delays" messages were displayed for all of the incidents, except for the RTA on 20/11/00 when only "Long Delay" was shown, and the RTA on 23/09/99, 03/10/00 when only "Delays" was shown.

(iii) Early diversion

For incidents occurring on the A3024 (Bitterne Road West and Northam Road), drivers could make an early diversion to the A27 Mansbridge Road at VMS H12, H14 and H15 (immediate diversion route at these VMS). Of the 11 incident cases studied, early diversion was in the range of 0-11% at VMS H14/H15 (Table 6.14), this varied with the causes and occurrence of the incident. In general, diversion rates were low. This was better illustrated by the accident scenario on 01/08/00, in which the accident resulted in the inbound direction of Bitterne Road West being closed from 11:10 to 11:49AM. However, only 5.9% of drivers made an early diversion to the A27 Mansbridge Road at VMS H14/H15. The most likely explanation of such low early diversion was that there was not much perceived benefit to drivers by taking the route of the A27 - Mansbridge Road.

Table 6.14 Early diversion rates at VMS H14/H15

	"Short Delays"	"Delays"	"Long Delays"
Diversion Rate (%)	0	0-3	0-11

(iv) Late diversion

Of the 11 incidents studied, late diversion rates were between 3.5% and 44.7% (for non-closure incidents). These varied with the causes, occurrences of the incidents and congestion levels. For the incidents occurring on Bitterne Road West and Northam Road, there were many junctions between the VMS and incident locations which could be used to divert. According to the detector results, most drivers diverted between Bursledon Road junction with Bath Road and Westend Road, the last two major junctions before the incident locations.

(v) Diversion and incident types

An incident of "Brokendown vehicle" occurred on Bitterne Road West on 10/11/99. During the incident (08:55-09:44AM), the "Long Delays" message was displayed. However, no early diversion was found to have occurred during the incident. Another incident of 'Shed Load' occurred on 20/11/00 with the VMS message of "Long Delays" being displayed during the incident (08:46-09:15AM), in which 7.5% of drivers made early diversions. A comparison of these two results indicated that drivers possibly did not consider a "Brokendown vehicle" to be serious, and would be cleared quickly . In general, most "Brokendown" vehicles can be moved to the roadside and incidents can be cleared within a short time, unlike accidents with vehicle damage and personal injury. However, some Brokendown vehicles did cause severe congestion, for example a "Brokendown" of lorry or bus. In this situation, the provision of quantitative information regarding status of congestion may have been more helpful for drivers to make an informed route choice decision.

Table 6.15 Results from other incident cases

Date	Incident					VMS		Diversion	
	Location	Road	Type	Severity	Duration	Message	Duration	Early (N11121F)	Late (N0111F&G/N07221E)
24/08/99	Bitterne Road West/Bullar Road	A3024	Roadworks	One lane blocked	07:00-19:00	17143 17142 17141	0742-1016 1016-1050 1050-	11% (07:22-09:30)	44.7% (07:22-10:16)
23/09/99	Bitterne Road West	A3024	RTA	One lane blocked	0910-0922	17122 17127 17114	0913-0922 0922-0931 0931-	0 (09:13-09:31)	7.5% (09:13-09:31)
13/10/99	Bitterne Road West/Bullar Road	A3024	Roadworks	One lane blocked	0700-1900	17142 17143 17142 17114	0743-0757 0757-0855 0855-0910 0910-	3% 07:43-09:10)	3.5% (07:43-09:10)
10/11/99	Bitterne Road West	A3024	Brokendown	One lane blocked	0852-0944	17182 17183 17182 17114	0855-0858 0858-0935 0935-0944 0944-	0% (08:55-09:44)	0% (08:55-09:44)
15/12/99	Bitterne Road West/Rail Bridge	A3024	Roadworks	One lane blocked	0700-1900	17141 17142 17143 17141 17114	0731-0753 0753-0802 0802-0908 0908-0940 0940-1007	2% (07:31-09:08)	9.3% (07:31-09:08)
23/03/00	Bitterne Road West/Chessel Crescent	A3024	Roadworks	One lane blocked	0700-1900	17141 17142 17143 17141 17114	0714-0740 0740-0802 0802-0905 0905-0916 0916-	0% (07:14-09:16)	17.1% (07:14-09:16)

Date	Incident					VMS		Diversion	
	Location	Road	Type	Severity	Duration	Message	Duration	Early (N11121F)	Late (N0111F&G/N07221E)
16/06/00	Northam Bridge/Prince Street	A3024	Roadworks	One lane blocked	0700-19:00	79141 79142 79143 20143 79142 79141	0700-0720 0720-0740 0740-0755 0755-1015 1015-1035	6.2% (07:20-10:55)	12.3% (07:20-10:55)
01/08/00	Bitterne Road West	A3024	RTA	Road closure	1100-1149	17122 17125 17142 17141	1103-1110 1110-1149 1149-1200 1200-	5.9% (11:03-11:49)	75.7% (11:03-11:49)
03/10/00	Northam Bridge	A3024	RTA	One lane blocked	0718-0725	79122 79114	0720-0725 0725-	0% (07:20-07:25)	0% (07:20-07:25)
20/11/00	Northam Bridge	A3024	Shed Load	One lane blocked	0842-0915	79183 79114	0846-0915 0915-	7.5% (08:46-09:15)	16.4% (08:46-09:15)
28/11/00	Northam Road/Brittania Road	A3024	Roadworks	One lane blocked	0700-1900	79141 79142 79143 79142 79141 79142 79111	0700-0717 0717-0750 0750-1040 1040-1150 1150-1534 1534-1900 1900	5.8% (07:50-10:40)	30.8% (07:00-12:00)

6.4 Case studies of incidents on the A33 (inbound)

6.4.1 Site descriptions

The A33 is a main northern approach to Southampton which connects central Southampton with Chandlers Ford and the M3 motorway (Figure 6.1). The road sections studied in this research included Bassett Avenue (1.3km) and The Avenue (1.4km). Both Bassett Avenue and The Avenue are single carriageway with two lanes in each direction.

During the study period from August 1999 to December 2000, there were 12 incidents of roadworks (involving 32 days) and 27 incidents of other types occurring on the A33 (Table 6.16). Of these incidents, 51.2% involved inbound traffic.

Table 6.16 Incidents occurring on the A33

	RTA	Roadworks	Brokendown	Other
Bassett Avenue	3	2	2	2
The Avenue	12	10	5	3

There are two VMS sites relevant to inbound traffic: VMS S08 and VMS H10. S08 is near Bassett Avenue junction with Glen Eyre Road, and H10 is on the A33 approaching to Chilworth Roundabout.

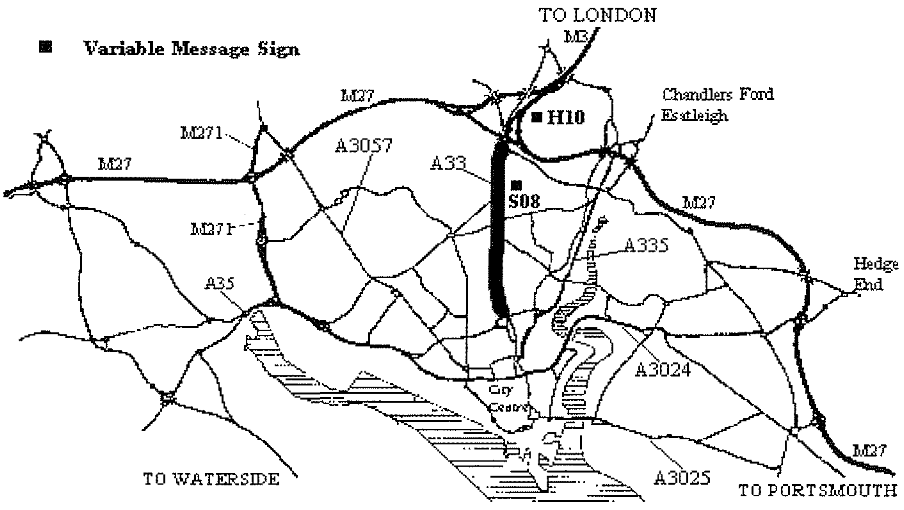

Figure 6.20 The A33 in Southampton

6.4.2 Accident on The Avenue junction with Burgess Road (10/11/00)

6.4.2.1 Locations of the incident, VMS and detectors

(i) Incident location

The accident occurred on 10/11/2000 at The Avenue junction with Burgess Road which affected the inbound traffic. The incident link is single carriageway with a one-way saturation flow of 3000 vehicle per hour. The normal inbound and outbound flows are about 1390 veh/h and 800 veh/h respectively (during AM peak). The accident started at 09:45 AM and ended at 10:36 AM. During the incident, one of the two lanes was blocked which resulted in severe congestion to inbound traffic.

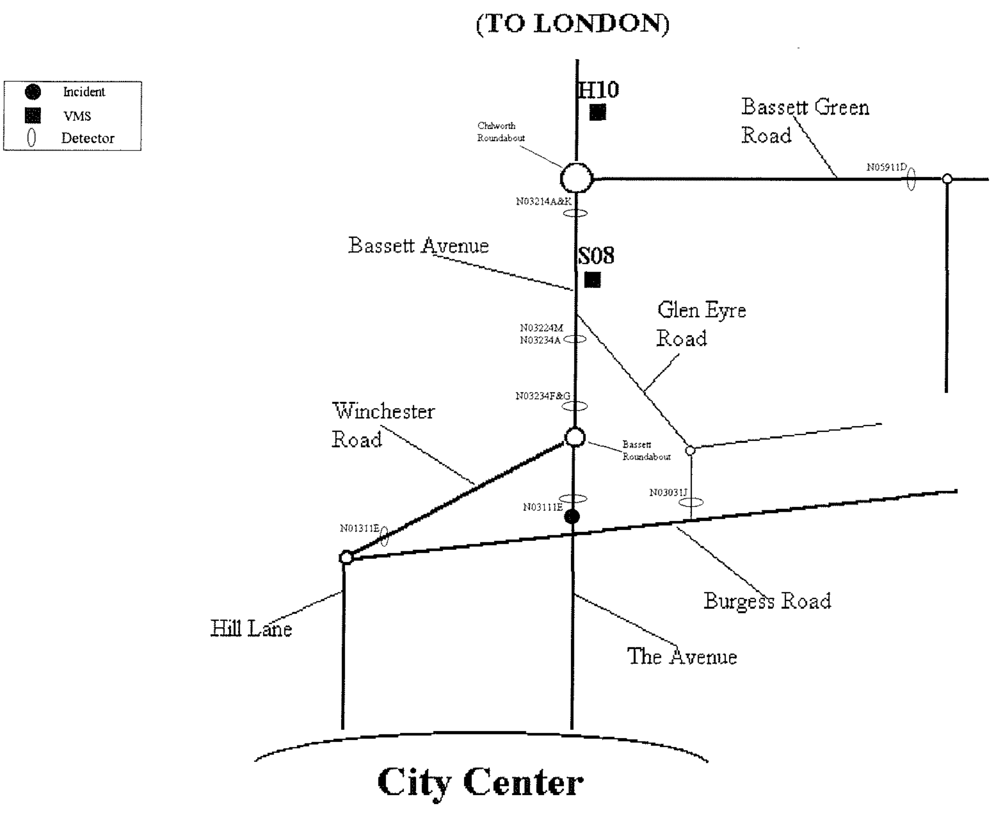

Figure 6.21 Relevant detector sites on the A33

(ii) Diversion routes

For those drivers passing VMS H10, the possible diversion routes were:

- Winchester roundabout--Winchester Road--Hill lane—
- Chilworth roundabout—Bassett Green Road—
- Bassett Avenue—Glen Eyre Road—

For those drivers passing VMS S08, the possible diversion routes are

- Winchester roundabout--Winchester Road--Hill lane—
- Bassett Avenue—Glen Eyre Road—

(iii) Messages displayed

Information about the accident was displayed via VMS ten minutes after its occurrence. During the incident, VMS S08 and H10 displayed the following messages as shown in Table 6.17.

Table 6.17 Messages displayed during the incident

Strategy Code	Message	Duration
ASTR 96122	ACCIDENT THE AVENUE DELAYS	10:00-10:36
ASTR 114	NO REPORTED INCIDENTS	10:36-

(iv) Traffic monitoring

Data relative to this incident case were collected from detectors in the vicinity of the incident and the seven most relevant detectors are shown in Figure 6.21. These are on The Avenue (N03111E), Winchester Road (N01311E), Bassett Avenue (N03214A&K, N03224M, N03234A, N03234F&G), and Glen Eyre Road (N03131J).

The incident occurred on a weekday, therefore the base traffic flow data, with which to compare the traffic flows on the day of the incident, was taken to be weekdays between 24th October 2000 and 24th November 2000. The average and the incident traffic flows during the incident preiod of 10:00 to 10:35 AM are shown in the Table 6.18.

Table 6.18 Traffic during the incident period of 10:00-10:36 (24/10/00-24/11/00)

	N03214A&K	N05911D	N03224M N03234A	N03111E	N01311E	N03131J
Normal (Average) (veh)	901	237	1146	574	393	137
Incident (10/11/2000) (veh)	870	284	1047	121	682	166

6.4.2.2 Results of data analysis

Traffic flows on relevant routes were measured to estimated diversion response to VMS. A comparison of the traffic flows with the average values indicate that:

- Traffic on Bassett Avenue (N03214A&K) was less than usual by 3.4% ($t=2.829$, $t_{\alpha/2}=2.093$, $df=19$, $\alpha=5\%$);
- Traffic on Bassett Avenue (N03224M and N03234A) was less than usual by 8.6% ($t=6.592$, $t_{\alpha/2}=2.101$, $df=18$, $\alpha=5\%$);

- Traffic on Winchester Road (N01311E) was greater than usual by 67.9% (t=-48.106, $t_{\alpha/2}$=2.101, df=18, α=5%);

- Traffic on The Avenue (N03111E) was less than usual by 78.9% (t=48.841, $t_{\alpha/2}$=2.109, df=17, α=5%);

- Traffic on Glen Eyre Road (N03131J) was greater than usual by 17.7% (t=-5.408, $t_{\alpha/2}$=2.086, df=20, α=5%)

- Traffic on Bassett Green Road (N05911D) was greater than usual by 16.5% (t=-7.767, $t_{\alpha/2}$=2.086, df=20, α=5%)

(i) At VMS H10

For those drivers passing VMS H10, Chilworth Roundabout was the decision point as to whether to divert to Bassett Green Road or stay on Bassett Avenue route. According to detector data at N03214A&K (Table 6.19), traffic on Bassett Avenue reduced by 3.4% (t=2.829, $t_{\alpha/2}$=2.093, df=19, α=5%). It is believed this traffic reduction was the results of diverting traffic and this was confirmed by the traffic increase at N05911D on Bassett Green Road.

Table 6.19 Results of statistics and test for traffic at N03214A&K, N05911D

Detector	Statistics			Test					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Lower	Upper
N03214AK	901	49.646	11.101	2.829	19	0.011	31.40	8.17	54.63
N05911D	237	27.869	6.082	-7.767	20	0.000	-47.24	-59.92	-34.55

According to detector results from detectors N03214A&K, there was no increase in occupancy during the incident (Figure 6.22). This indicated that the queues did not stretch back to the decision point of Chilworth Roundabout, and therefore, the diversion to Bassett Green Road at VMS H10 was entirely the result of information (i.e. an early diversion).

It can be seen that the diversion rate to Bassett Green Road was low. One of the most likely reasons for this was the substantial extra distance involved in using that route. For those drivers heading to Central Southampton, the distance increases by about 40% when taking the route of Bassett Green Road. In addition, there are more signalised junctions on the route via Bassett Green Road than those on the route of Winchester Road – Hill Lane. It was quite possible that the drivers who diverted through the route of Bassett Green Road were those who were with their destination in the areas of Bassett and the University. However, this is very difficult to be confirm with the current monitoring available.

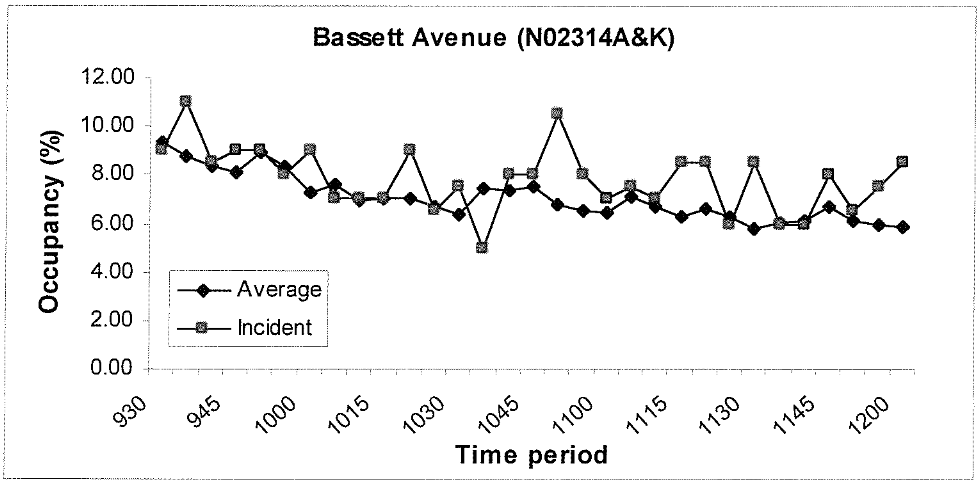

Figure 6.22 Occupancy on Bassett Avenue southbound (N03214A&K)

(ii) At VMS S08

For those drivers passing VM S08, the Bassett Avenue junction with Glen Eyre Road is the first decision point to decide whether or not to divert. According to detector data at N03224M and N03234A (Table 6.20), the traffic reduced by 8.6% (statistically significant). Checking detector data (N03131J) indicated that traffic on Glen Eyre Road increased by 29 vehicles during the accident, which represented a diversion rate of 2.6% (statistically significant).

Table 6.20 Results of statistics and test for traffic at N03224M, N03234A and N03111E

Detector	Statistics			Test					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Lower	Upper
N03224M N03234A	1146	65.745	15.083	6.592	18	.000	99.42	67.73	131.11
N03131J	137	24.693	5.388	-5.408	20	0.000	-29.14	-40.38	-17.90

The detector data at N03224M&N03234A show that the queues did not stretch back to the 'decision point 'of Bassett Avenue junction with Glen Eyre Road (Figure 6.23), and therefore any diversion to Glen Eyre Road can be taken as an early diversion.

Glen Eyre Road is a narrow residential road, with saturation flow of 800 veh/h, compared to 1700 veh/h on Winchester Road and 3000 veh/h on The Avenue. The relatively low capacity might be the main reason for drivers not diverting on to the route of Glen Eyre Road.

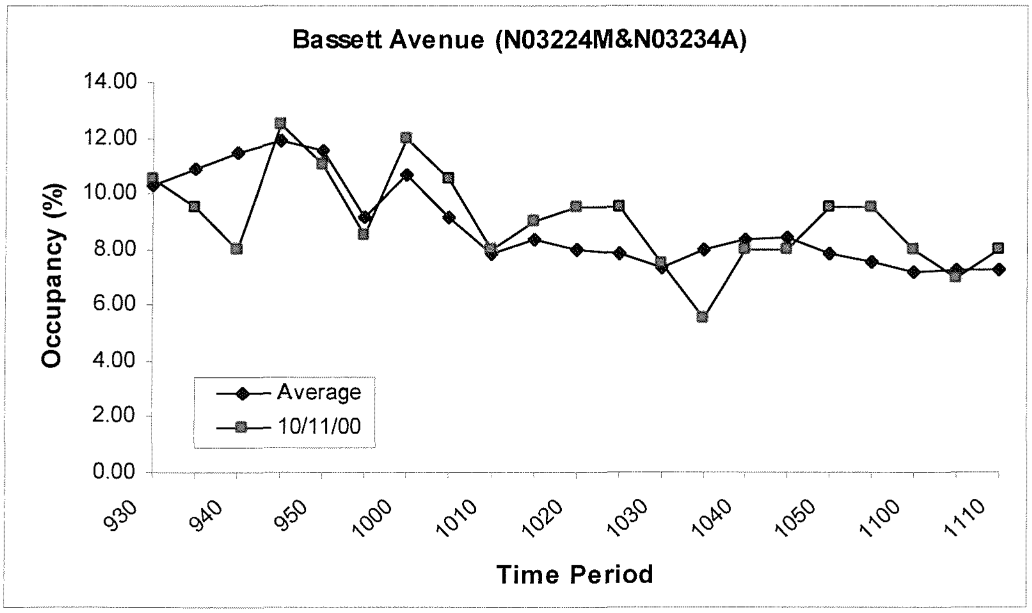

Figure 6.23 Occupancy on Bassett Avenue southbound (N03224M&N03234A)

(iii) At the 'decision point' of Bassett Avenue/Winchester Road roundabout

The Bassett Roundabout was a decision point for drivers decide whether to stay on their usual route of The Avenue or to divert to Winchester Road. Detector data showed that during the time period of 10:00-10:36, the traffic on Winchester Road (N01311E) increased by 67.9%, from 405 vehicles to 682 vehicles (Table 6.21). The proportion of traffic using Winchester Road increased from 36.1% to 55.2%. This represents a diversion rate from The Avenue to Winchester Road of some 22.6% (Figure 6.24).

Table 6.21 Results of statistics and test for traffic at N01311E and N03111E

Detector	Statistics			Test					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Lower	Upper
N01311E	393	26.220	6.015	-48.106	18	0.000	-289.37	-302.01	-276.73
N03111E	574	39.316	9.267	48.841	17	0.000	452.61	433.06	472.16

The results in Figure 6.25 show that during the time period of 09:50-10:50, the queues stretched back to Bassett Roundabout. This meant that the drivers diverted to Winchester Road after having encountered queues on the incident route.

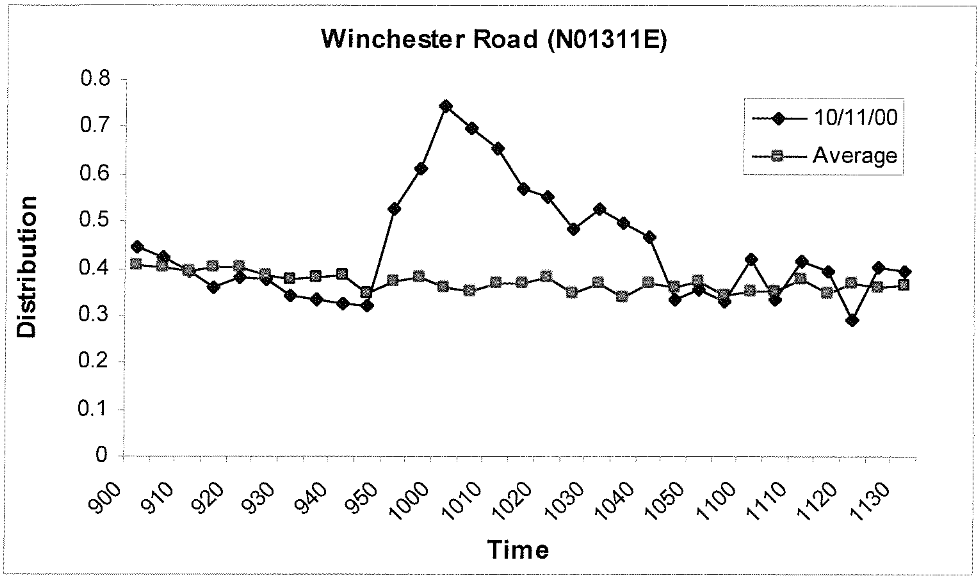

Figure 6.24 The proportion of traffic using Winchester Road

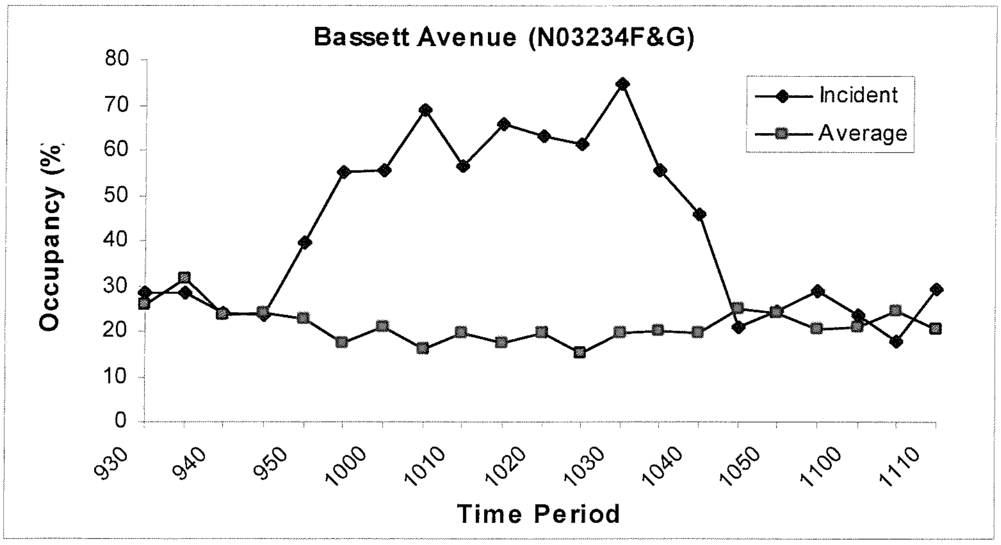

Figure 6.25 Occupancy on Bassett Avenue (N03234F&G)

6.4.2.3 Conclusions

Based on the results from this incident case, the following conclusions can be drawn about the drivers' diversion response to VMS:

- The rate of early diversion was low in this incident case. 3.4% of drivers made diversion to Bassett Green Road at VMS H10, and 2.6% of drivers made diversion to Glen Eyre Road at VMS S08 (Table 6.22).

Table 6.22 Early and late diversion

Decision Point	Early Diversion (%)	Late Diversion (%)
Chilworth Roundabout	3.4	0
Bassett Avenue junction with Glen Eyre Road	2.6	0
Bassett Roundabout	0	22.6

- Compared to early diversion, drivers appeared to be more likely to divert after the VMS information received was confirmed by the observed queues. In this incident case, 22.6% of drivers diverted to the route of Wichester Road – Hill Lane.

- For the incident location at The Avenue junction with Burgess Road, Bassett Green Road, Glen Eyre Road and Winchester Road are the three alternative routes. Compared with the other two routes, Winchester Road is more attractive.

6.4.3 Results from other incident cases on the A33

All the incidents occurring on the A33 during the study period were investigated (not including those too minor or where detector data was missing). Eight incidents involving inbound traffic were studied in detail. The main results from the incidents studied are summarised in Table 6.23.

(i) Incident types and severity

All the eight incidents studied were road traffic accidents (RTA). The severity of the incidents were "one of the two lanes blocked", except for the one on 06/12/00, in which the RTA resulted in the road being closed.

(ii) VMS messages displayed

The message of "Delays" was displayed in all of these eight incidents. No message of 'Short Delays' was displayed and the 'Long Delays' message was displayed only on 06/12/00. This made it impossible to compare drivers' responses to different messages displayed.

(iii) Incident location and diversion routes

The road sections of the A33 studied (Bassett Avenue and The Avenue) are all within the urban area. Along the 2.7 km road sections, there are nine main junctions which can be used for diversion. The closer the incident to the City Centre, the more diversion routes are available. Taking the accident case on 06/12/00 as an example, in which the incident occurred between Chilworth Roundabout and Bassett Avenue junction with Glen Eyre Road, there was only one diversion route was available, that via Bassett Green Road. However, for the incident on 01/08/99 occurring at The Avenue junction with Lodge Road, eight routes available for diversion.

(iv) Early diversion

Early diversion was only found on 04/10/00 and 10/11/00 in which 5.8% and 3% of drivers diverted respectively. It can be seen that the observed early diversion rates were low (compared with the diversion rate of 12.6% on the A35 Redbridge Causeway). One likely reason for such low values of early diversion may have been that drivers could use one of the many alternative routes available between the decision point and the incident locations.

When an incident occurred close to decision points, it would be easy for the queues to tail back to the decision point. For example, it took less than 5 minutes for the queues to tail back to the decision point of Bassett Roundabout in the accident case on 10/11/00. In this situation, it was difficult to observe any early diversion.

(v) Late diversion

Late diversions were widely found in the incident cases studied, with the values in the range between 6.7% and 22.6%. The diversion rates varied with the locations, occurrence and duration of the incidents. The largest late diversion was found during the accident on Bassett Avenue/Burgess Road junction (10/11/00), where up to 22.6% drivers diverted to avoid the congestion caused by the accident. It can be seen that late diversion rates were much higher than early diversion rates which suggests that drivers were more likely to divert after their acquired information was confirmed by the observed queues caused by the incidents. It is not clear how much the VMS signs contributed to such late diversion because no data is available for comparing diversions before and after VMS installation.

Table 6.23 Main results from other incident cases on the A33

Date	Incident					VMS		Diversion	
	Location	Direction	Type	Severity	Duration	Message	Duration	Early	Late
10/08/99	The Avenue/Lodge Road	Inbound	RTA	50%	0736-0752	96122 96114	0736-0752 0752-	0% (N01311E)	19.6% (N04141E)
02/06/00	The Avenue/Winn Road	Inbound	RTA	50%	0825-0848	96122 96124 96114	0825-0848 0848-0857 0857-	0% (N01311E)	11.8% (N04141E)
07/06/00	The Avenue/Burgess Road	Inbound	RTA	50%	0700-0715	96122 96114	0700-0715 0715-	0 (N10311E)	6.7% (N0311E)
04/10/00	The Avenue/ Westwood Rd	Inbound	RTA	50%	1720-1739	96122 96127 96114	1720-1739 1739-1753 1753-	5.8% (N04141E, N01311E)	13.7% (N04141E, N01311E)
09/10/00	The Avenue/Bassett Road	Inbound	RTA	50%	1200-1217	96122 96127 96114	1200-1217 1217-1222 1222-	0% (N01311E)	7.1% (N04141E)
11/10/00	Bassett Av Approaching Winchester rbt	Inbound	RTA	50%	1723-1805	14122 14114	1723-1805 1805-	0% (N05911D)	8.5% (N03224R&S)
10/11/00	The Avenue/ Burgess Road	Inbound	RTA	50%	1000-1036	96122 96114	1000-1036 1036-	3% (N05911D, N03214A&K, N03131J, N03224M)	22.6% (N01311E)
06/12/00	Bassett Av/Glenn Eyre Road	Inbound	RTA	100%	1400-1448	14122 14123 14127 14114	1400-1411 1411-1448 1448-1453 1453-	--	11.7% (Bassett Green Road, N05911D, N03224R&S)

6.5 Case studies of incident on the A335 (inbound)

6.5.1 Site descriptions

The A335 is a main northern approach to Southampton which connects central Southampton with Chandlers Ford, Eastleigh and Junction 5 of the M27 (Figure 6.26). The main road sections studied on the A335 include Stoneham Way (0.6km), Thomas Lewis Way (1.3km), Bevois Valley Road (0.3km) and Onslow Road (0.5km). During the study period from August 1999 to December 2000, 20 incidents of non-roadworks and 4 incidents of roadworks occurred on the A335 (Table 6.24). Of these incidents, 92.5% involved inbound traffic.

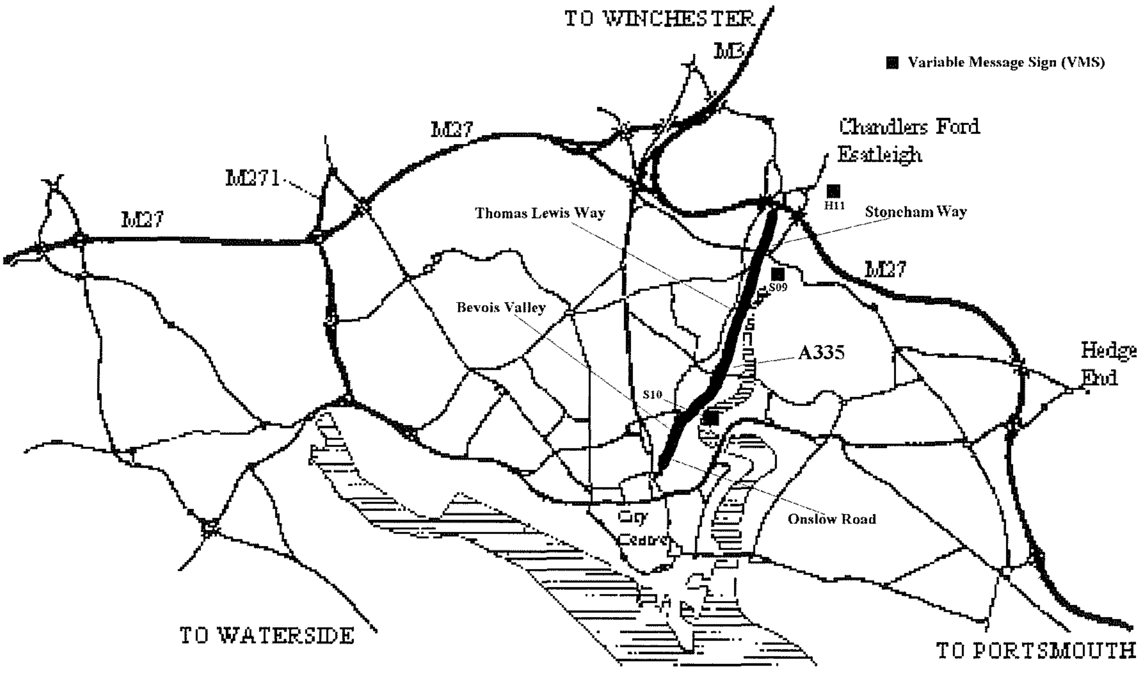

Figure 6.26 The A335 in Southampton

Because of the road closure, temporary signs were used at locations near Onslow Road to inform those drivers passing the roadwork location before it was started. Tis could causes diversions in addition to those resulting form the VMS.

(ii) Detector sites and data collection

The detectors relevant to this scenario are as shown in Figure 6.28. Detectors near VMS S09 include N05151A&K (Stoneham Way), N05121G&H (High Road), N05141G (Thomas Lewis Way). Detectors near VMS S10 include N06241(Thomas Lewis Way), N06211E (Lodge Road); N06231A (Thomas Lewis Way).

The incident occurred on a weekday, therefore, the base traffic flow data, with which to compare the traffic flows on the day of the incident, was taken to be over weekdays two weeks before the incident, i.e. from 02/08/1999 to 13/08/1999.

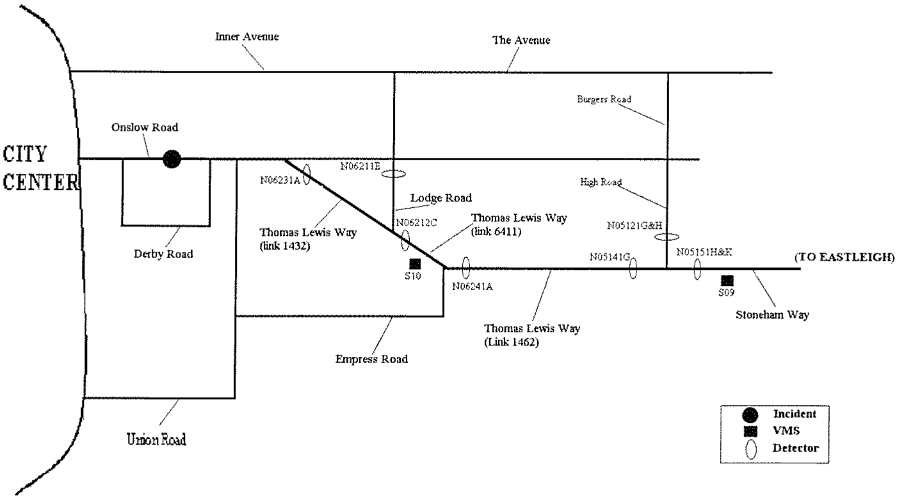

Figure 6.28 Locations of incident, VMS and detectors

6.5.2.2 Results of data analysis

(i) At VMS S09

For those drivers passing VMS S09, the Stoneham Way junction with Thomas Lewis Way was the 'decision point' either to stay on their usual route of Thomas Lewis Way or to divert to High Road (Figure 6.28). Before further analysis, the traffic before the 'decision point' was checked to make sure that the traffic arrival rate on the incident day was usual. The null hypothesis is that there was no difference in arrival rates between incident and normal traffic on Stoneham Way (N05151H&K). Compared with the usual value, the traffic was marginally greater than usual by 0.6% (Table 6.25 and Table 6.26), and was not statistically significant based on the t-test results ($t=-0.966$, $t_{\alpha/2}=2.306$, $df=8$, $\alpha=5\%$), therefore the null hypothesis is accepted. This meant that the traffic on the incident day was not different from usual and there was no early diversion before the Stoneham Way junction with Thomas Lewis Way.

The analysis of detector data showed that the traffic on Thomas Lewis Way (N05141G) reduced by 2.3%, this was statistically significant based on the t-test results ($t=3.056$, $t_{\alpha/2}=2.306$, $df=8$, $\alpha=5\%$). However, the traffic on High Road (N05121G&H) increased by 1.3% which was not statistically significant ($t=-1.621$, $t_{\alpha/2}=2.306$, $df=8$, $\alpha=5\%$).

Table 6.25 AM peak traffic (07:00-09:30) at detectors near to VMS S09

	N05151H&K (Veh)	N05121G&H (Veh)	N05141G (Veh)
Normal Traffic (Average)	3520	1998	2482
Incident Traffic (16/08/99)	3543	2024	2423

Table 6.26 Results of statistics and test for traffic data near to VMS S09

Detector	Statistics			Test					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Lower	Upper
N05151A&K	3520	71.463	23.821	-0.966	8	0.363	-23.00	-77.93	31.93
N05121G&H	1998	48.729	16.243	-1.621	8	0.144	-26.33	-63.79	11.12
N05141G	2482	57.916	19.305	3.056	8	0.016	59.00	14.48	103.51

(ii) At VMS S10

a) Diversion routes

For drivers receiving information from VMS S10, there were three diversion routes available:

- Thomas Lewis Way----Lodge Road----
- Thomas Lewis Way ----Bevious Valley Road----
- Thomas Lewis Way ----Empress road----

Firstly, the normal arriving rate before VMS S10 was tested. The null hypothesis is that there was no difference in arrival rates between incident and normal traffic before the Thomas Lewis Way junction with Empress Road (N06241). Compared with the average value, the traffic at N06241A was greater than normal by 0.8% (Table 6.27 and Table 6.28). This was not statistically significant ($t=0.299$, $t_{\alpha/2}=2.306$, $df=8$, $\alpha=5\%$), thus, the traffic on the incident day was not different from usual and there was no significant diversion prior to the Thomas Lewis Way junction with Empress Road.

The analysis of traffic data on the diversion routes indicated that a significant number of vehicles diverted during the time period of 07:00-09:30. Traffic increased by 8%, from 1109 vehicles to 1197 vehicles on Lodge Road (N06211E), and traffic increased by 642 vehicles on Empress Road. There were 705 vehicles stayed on their usual route of Thomas Lewis Way—Bevois Valley and then used local residential roads to avoid the incident location. This accounted for 49.1% of the total traffic.

Table 6.27 AM peak traffic (07:00-09:30) near to VMS S10

	N06241A (Veh)	N06211E (Veh)	N06231A (Veh)
Normal Traffic (Average)	2885	1109	1435
Incident (16/08/99)	2908	1197	705

Table 6.28 Results of statistics and test

Detector	Statistics			Test					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
								Lower	Upper
N06241A	2885	63.020	21.007	-1.111	8	0.299	-23.333	-71.775	25.108
N06211E	1109	34.362	11.454	-7.644	8	0	-87.556	-113.969	-61.142
N06231A	1435	45.799	15.266	47.847	8	0	730.444	695.240	765.649

6.5.2.3 Early and late diversions

(i) Early diversion

- At VMS S09

According to detector data, there was no significant traffic reduction after the Stoneham Way junction with Thomas Lewis Way (N05141G). There was insufficient evidence to show that drivers made early diversions at VMS S09.

- At VMS S010

The results shown in Figure 6.29 indicate that during the period of 07:00-09:30, there was no additional increase in occupancy on Thomas Lewis Way at N06231A (i.e. incident route), and the queues did not stretch back to the decision point of the Thomas Lewis Way junction with Lodge Road. Thus, drivers' diversions at S10 were made without having encountered queues caused by the incident.

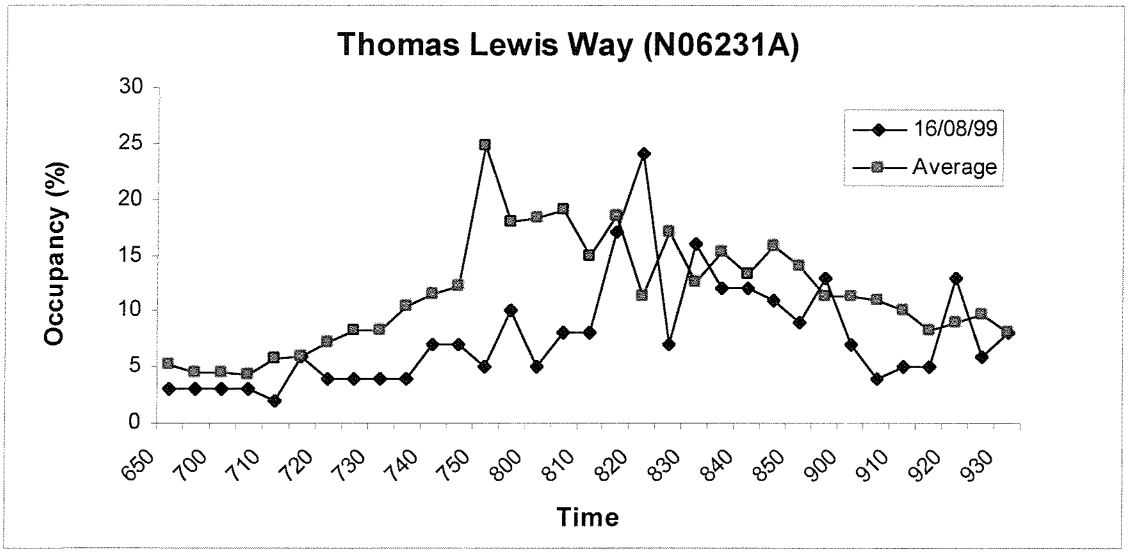

Figure 6.29 Occupancy on Thomas Lewis Way at N06231A

According to detector data (N06211E), traffic on Lodge Road increased by 88 vehicles during the time period of 07:00-09:30, which represented a diversion rate of 6.1%. The results in Figure 6.30 and Figure 6.31 show that the diversion rate to Lodge Road route was dependent on the congestion on the diversion route. During the period 07:00-07:30 when there was very little congestion on Lodge Road at N06211E (Figure 6.31), as many as 49% of drivers diverted to Lodge Road. During the period of 07:30-09:00, when Lodge Road became congested because of diverting traffic (significant additional increase in occupancy), the diversion rate dropped. When the congestion on Lodge Road reduced, the diversion rate to Lodge Road rose again.

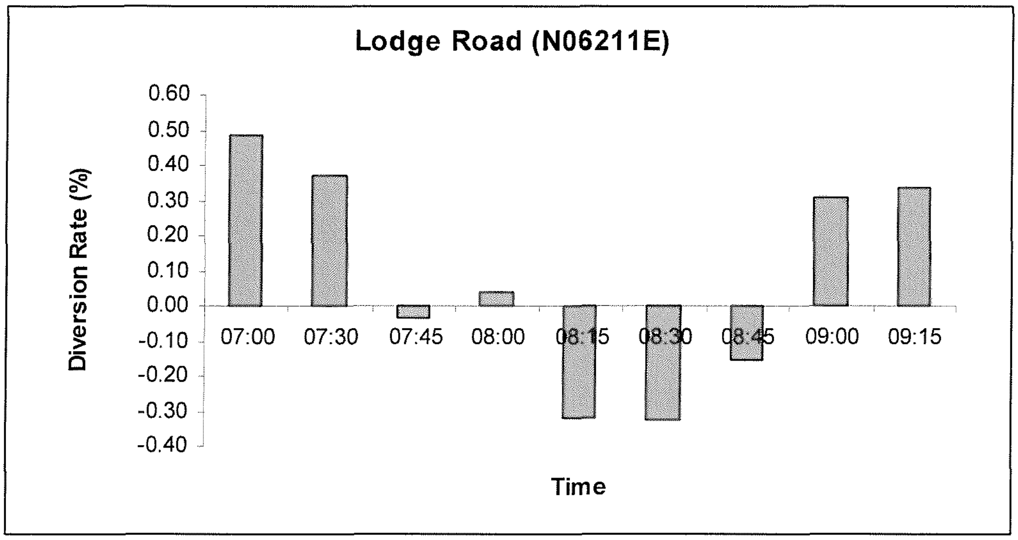

Figure 6.30 Diversion rate to Lodge Road

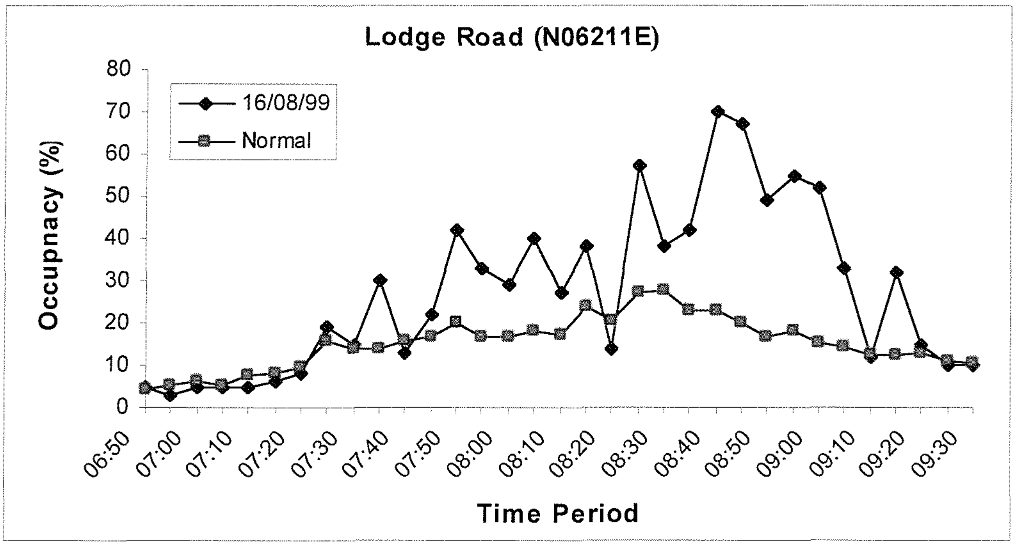

Figure 6.31 Occupancy on Lodge Road

During the period from 08:30 to 09:15, the diversion rates became 'negative', indicating that the availability of capacity on Lodge Road was reduced to lower than the usual level. This affected not only the incident drivers, but also some regular users of Lodge Road as well.

(ii) Late diversion

During the incident, the available capacity on Lodge Road was substantially reduced by the diverting traffic which made queues build up and stretch back to Thomas Lewis Way (link 6411). Because of the observed the queues, some drivers diverted through Empress Road. According to the detector data, some 642 vehicles made such a diversion which represented a diversion rate of 44.7%. The queue blocking back up to Thomas Lewis Way was confirmed by the occupancy measurement at N06212C (Figure 6.32)

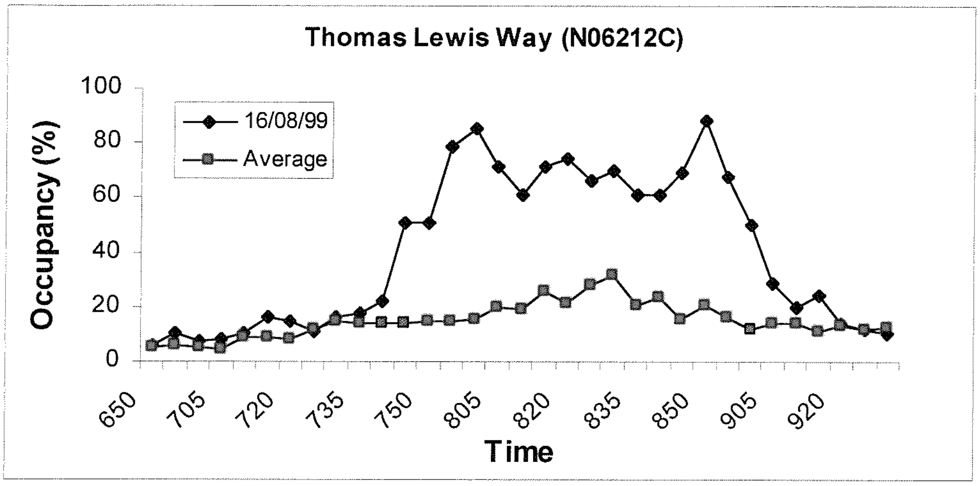

Figure 6.32 Occupancy on Thomas Lewis Way at N06212C

6.5.2.4 Discussion

(i) Low diversion rate to Lodge Road

Lodge Road is the main diversion route at VMS S10. However, only 6.1% of drivers diverted to Lodge Road during the period of 07:00-09:30. The most likely reasons for such a low diversion rate to Lodge Road are:

- The first road section on Lodge Road route (N06211A) was a short link of 50m in length between two signalised junctions. The available capacity of Lodge Road was substantially reduced by the diverting traffic which resulted in the queues stretching back to the upstream link. The tail back of the queues on Lodge Road dis-encouraged drivers from using Lodge Road.

- Some drivers were familiar with the road network near the incident location and confident that they could make late diversion to avoid the congestion.

- Some driver's destinations were close to, or before, the incident. (According to the CONTRAM O-D matrix, 12.7% of drivers whose original route pass through Thomas Lewis Way ended their trips before the incident location). Such drivers would not divert to Lodge Road.

(ii) Early diversion at VMS S09

Drivers passing the S09 could make early diversion by taking the route High Road – Buregess Road - The Avenue. The detector data indicated that no drivers made such early diversions on the first day of the roadworks, although static signs were displayed before the roadwork to notice drivers of the roadwork. There could be the following reasons for drivers not making early diversion at VMS S09:

- Drivers did not see the signs because the signs were small and at locations too low which made them difficult for drivers to see clearly, especially for those drivers driving through with high speeds.

- Drivers forgot the date on which the roadwork started.

- Drivers had seen the signs and knew the roadwork, but did not think it would benefit to divert to alternative routes.

(iii) Routing behaviour on the following days

On the second day of the incident (17/08/99), the traffic on Thomas Lewis Way (N05141G) reduced by 180 vehicles (Table 6.29) during the AM peak period of 07:00-09:30 (compared with that of 59 vehicles on 16/08/1999), this represented a diversion rate of 7.2%. On the third day (18/08/1999), the corresponding traffic reduction and diversion rates were 167 vehicles and 6.7% respectively. The traffic diversions were confirmed by the increases in traffic on Burgess Road (N05121G&H), 104 vehicles on 17/08/1999 and 139 vehicles on 18/08/1999. Both the traffic decrease on Thomas Lewis Way (N05141G) and traffic increase on Burgess Road (N05121G&H) were statistically significant. This illustrated that some drivers learned from the experience on the first day of the roadworks.

Table 6.29 Traffic near to VMS site of S09

	Diversion Route (N05121G&H) (Veh)	Incident Route (N05141G) (Veh)
16/08/99 (The 1st day)	2024	2423
17/08/99 (The 2nd day)	2102	2302
18/08/99 (The third day)	2137	2315

6.5.2.5 Conclusions

Based on the results from this incident case, the following conclusions can be drawn relating to the drivers' diversion response to VMS:

- Few drivers diverted at VMS S09 to the route of High Road--Burgess Road--The Avenue--. Most drivers diverted at VMS S10 which was closer to the incident location than VMS S09. Comparing the routes between High Road--Burgess Road--The Avenue and Thomas Lewis Way--Lodge Road, nearly half of the former route was 30 mph roads, whilst most of the later route was 40 mph roads. In addition, the High Road – Burgess Road – The Avenue route was 0.8 mile longer.

- Traffic condition has significant effects on the diversion rates. Taking the route of Lodge Road as an example, when there was little congestion on the diversion route, up to 49% of drivers made an early diversion to Lodge Road in response to the 'road closure' message via

VMS. However, when Lodge Road became congested, few drivers chose Lodge Road to divert.

- Comparing the diversion rates between the first and the following days of the incident indicated that for an incident lasting several days, drivers were more likely to believe VMS information and make early diversion after previous experience of travel on the first day of the incident.

Table 6.30 Incidents on the A335 inbound

Date	Incident					VMS		Diversion	
	Location	Direction	Type	Severity	Duration	Message	Duration	Early	Late
16/08/99	Onslow Road	Both	Roadworks	Closure	0700-19:00	15145/15545	0700-19:00	6.1% (N06211E)	51% (N06231A)
13/09/00	Thomas Lewis Way/Railway Bridge	inbound	RTA	One lane Blocked	0913-	97122 97121	0913-0923 0923	0% (N05131D&E) (N06241A)	24.5% (N05141G) (N062141A)

6.6 Conclusions

The routing effects of VMS were investigated by analysing incident cases occurring on the A35, A3024, A33 and A335. Both early and late diversions at VMS were found, which are very important for assessing the routing effects of VMS. The following conclusions can be drawn based on the incident cases studied:

- The results of the incident case studies indicate that VMS can significantly affect driver's route decisions. Early diversion is a good indication of drivers' response to VMS information because it is made before drivers have encountered queues on incident routes. For non-closure incidents, the early diversion rates on the A33, A35, A335 and A3024 are summarised in Table 6.31. On the A35, up to 34% of drivers made early diversion. However, on the A3024, A33 and A335 the early diversion rates were much smaller.

Table 6.31 Early Diversion

Route	Early Diversion
A33	0-5.8%
A35	0-34%
A335	0-6.1%
A3024	0-11%

- In most incident cases, late diversion rates were higher than the corresponding early diversion rates. This indicated that drivers were more likely to divert after the VMS information was confirmed by the observed queues. For incidents when capacity was reduced by 50%, the late diversion rates on the four corridors are shown in Table 6.32. The late diversion rates clearly varied with incidents, VMS messages and availability of diversion routes. .

Table 6.32 Late Diversion

Route	Late Diversion
A33	0-22.6%
A35	0-64%
A335	0-51%
A3024	0-30.8%

- The number of viable alternative routes is one of the most important factors which influence the rate of early diversion. When there are many viable alternative routes between decision points and incident locations, drivers generally continue their journey until they encounter unexpected queues on their normal routes. The results of the incident case studies show that there were lower early diversion rates with more viable alternative routes. For example, when incidents occurred on the A35 Redbridge Causeway eastbound, A326 Totton Western Bypass was the only alternative route for those passing VMS, and up to 34% drivers made early diversion. However, when the incidents occurred on the A33, A335 and A3024, there were several viable alternatives available for diversion, and most of the observed early diversion rates were in the range of 0-10%, much lower than those on the A35.

- “Short Delays”, “Delays” and “Long Delays” were the main messages displayed regarding the status of congestion levels. Very little diversion has been found during the display of “Short Delays” from the incident cases studied. However, significant diversion has been found during the displays of “Delays” and “Long Delays”. In general, diversion rates increased as the strength of messages increased.

- In addition to flow data, speed and occupancy data from SCOOT detectors were used in the analysis of incident cases. These data were very useful to obtain a better understanding of drivers’ route choice behaviour during incident/VMS.

- More detectors at strategically designed locations are needed to better study drivers’ diversion responses to VMS information. Detector location is very important for observing drivers’ diversion responses to VMS information. Ideally, detectors should be on the first link after decision points on both incident and diversion routes. Because most current detectors are used to serve the urban traffic control in Southampton, they are at locations near to signalised junctions. To study drivers' diversion responses to VMS, the traffic data both before and after decision points are equally important. It is difficult to get suitable data on diversion traffic when drivers divert using the routes without detectors or where the detectors are too far from the decision points. Taking incidents on the A3024 as examples, there were no suitable detectors (incident and diversion routes) to observe traffic passing VMS H12 and diverted to the A27 Mansbridge Road, which made it impossible to study the routing effects of drivers at VMS H12.

- It can be seen that diversion rates are incident specific. In the study period of 01/08/99-20/12/00, the A35 Redbridge Causeway had the highest frequency of incidents and most suitable incidents for case study, however, few suitable incidents were found on the A335. Large number and long terms of incident case studies are needed to strength the conclusions from incident case studies, especially on the A335.

7 Assessing VMS impacts on network efficiency

7.1 Introduction

In this section, the three incident cases (described in Chapter 6) which occurred on the A35 Redbridge Causeway (27/03/00), A3024 Northam Road (28/11/00) and A335 Onslow Road (16/08/99) were further studied by using the 'Single-Day' version of RGCONTRAM model. The objective of this research is to assess the impacts of VMS on network traffic efficiency based on observed diversion rates.

The basic approach used in this section is to compare the traffic efficiencies in the incident scenarios (based on observed diversion rates) with those in " do nothing" scenarios to assess VMS effects on traffic efficiency. In the assessments, the following four indicators were used:

- travel time
- travel distance
- congestion index
- travel speed

The number of diverting drivers and diversion rates in the three incident scenarios are listed in Table 7.1. As analysed in Chapter 6, 1036, 1150 and 81 vehicles diverted during the AM peak period of 07:00-09:30 which represent diversion rates of 28%, 42% and 6.1% in the three incident cases respectively (Refer to Chapter 6.2.2.2, 6.3.2.2 and 6.5.2.2 for the number of diverting vehicles and the correspondent diversion rates). These are the total diversions during the AM peak period of 07:00-09:30 which include both early and late diversion. Because only peak O-D matrixes were available in Southampton, the assessment of VMS effects on traffic efficiency were based on the modelling results in the AM peak period from 07:00 to 09:30.).

Table 7.1 Observed diversions (07:00-09:30)

	A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
Diverting vehicles	1036	1150	81
Diversion Rate	28%	42%	6.1%

7.2 Travel time

7.2.1 Journey time savings of incident drivers

The journey time savings of incident drivers are illustrated in Figure 7.1. It can be seen that, in the Redbridge Causeway scenario, the incident drivers benefited from diversion, with the journey time-savings of 1052 veh-h when 28% of drivers diverted (Table 7.2). In the Northam Road and Onslow Road scenarios, the journey time-savings of incident drivers were 1210 veh-h and 63.2 veh-h when the 42% and 51% incident drivers diverted respectively.

The results in Figure 7.1 show that in the Redbridge Causeway scenario, the maximum journey time-savings of incident drivers would have been reached when about 90% drivers (those eligible to divert) had diverted, with the journey time-savings of 1891.4 veh-h. In the Northam Road scenario, the maximum journey time-savings of incident drivers would have been reached when about 60% drivers had diverted, with the value of journey time-savings of 1400 veh-h. In the Onslow Road scenario, the maximum journey time-savings of incident drivers would have been reached when about 20% drivers had diverted, with the value of journey time-savings of 107.2 veh-h.

It can be seen from the results shown in Figure 7.1 that the journey time-savings of incident drivers in the Redbridge Causeway and Northam Road Scenarios are much higher than those in the Onslow Road scenario. One of the main reasons for this was that the number of drivers diverting in the Redbridge Causeway and Northam Road scenarios were much more than those in the Onslow Road scenario. Some 1036 and 1150 drivers diverted in the Redbridge Causeway and Northam Road scenarios, while only 81 drivers diverted in the Onslow Road scenario.

Table 7.2 Journey Time-savings of Incident Drivers.

	A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
No. of Drivers Diverting (veh)	1036	1150	81
Journey Time-savings of Incident Drivers (Veh-h)	1052	1210	116

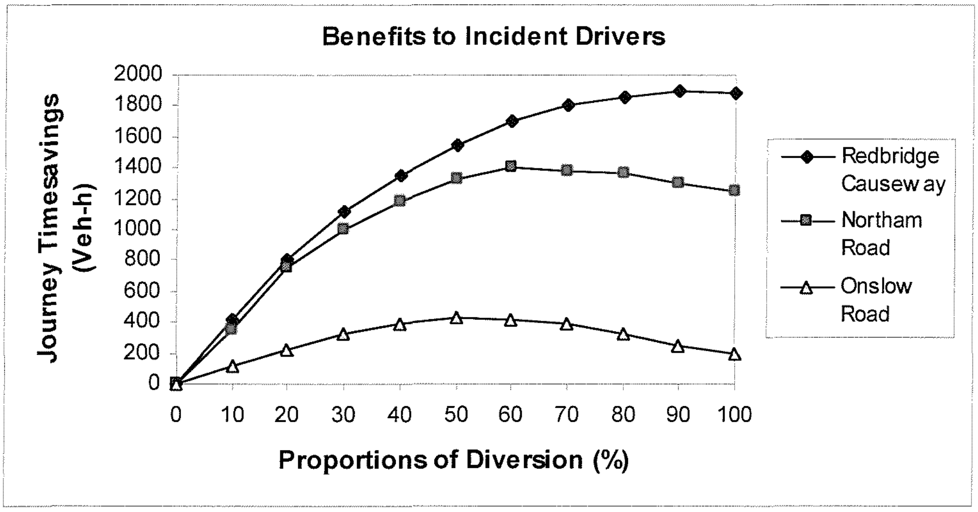

Figure 7.1 Journey time-savings of incident drivers

7.2.2 Journey time savings of non-incident drivers

The journey time-savings of non-incident drivers in the three incident scenarios are illustrated in Figure 7.2. It can be seen that non-incident drivers disbenefit from VMS in all of these three incident scearios. In the Redbridge Causeway scenario, non-incident drivers disbenefited during the display of VMS, with journey time increasing by 290 veh-h when the 28% of drivers diverted. In the Northam Road and Onslow Road scenarios, the journey time of non-incident drivers increased by 1405 veh-h and 15 veh-h when the 42% and 6.1% of the drivers diverted respectively.

The results shown in Figure 7.2 indicated that the disbenefits to non-incident drivers increase as the proportions of diversion increase. In the three scenarios, the non-incident drivers in Northam Road scenario disbenefited most during the VMS, whilst the non-incident drivers in the Onslow Road scenario disbenefited least. The incident location and the diversion routes for these two scenarios were all within the urban areas. However, there was less spare capacity on the diversion routes in the Northam Road scenario than that in the Onslow Road scenario. When in 'do nothing' scenarios, the v/c (volume/capacity) ratio of the most congested link on the diversion routes (through the St Denys Road junction with Priory Road) was 0.90 for the incident location on Northam Road, whist the v/c ratio of the most congested link on the 'diversion route' in the Onslow Road scenario (through Lodge Road) was 0.86, lower than that in Northam Road scenario. When 42% of drivers diverted in the Northam Road scenario, the v/c ratio of the most congested link increased from 0.90 (when in 'do nothing' scenario) to 1.01 (Table 7.3), which was close to the congestion level on the incident route. Diversion shifted the congestion from the incident route to the diversion route. In the Onslow Road scenario, the v/c ratio increased from 0.86 to 0.90 when 6.1% drivers diverted.

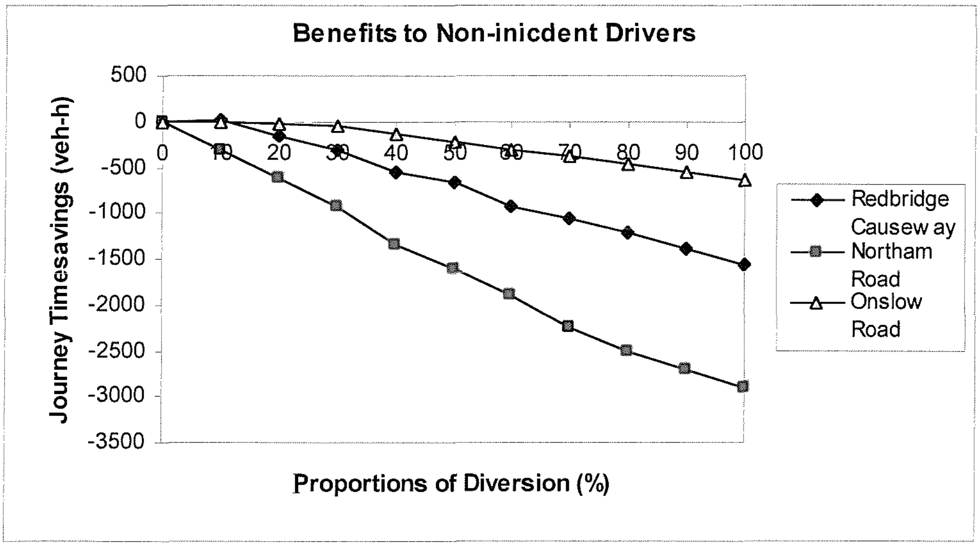

Figure 7.2 Total journey time of non-incident drivers

Table 7.3 V/C ratio on diversion routes for the three incidents

		A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
Distance of the diversion routes		12.4 km	4.6 km (through St Denys Road)	2.3 km
The V/C ratio of the most congested link on the incident routes	Without VMS	1.09	1.05	1.06
	With VMS	0.88	0.96	0.80
The V/C ratio of the most congested link on the diversion routes	Without VMS	0.97	1.01	0.90
	With VMS	0.89	0.90	0.86
Journey time of non-incident drivers (veh-h)	Without VMS	15722	15415	16095.7
	With VMS	16014	16820	16103.9

7.2.3 Journey time savings of network drivers

The journey time-savings to network drivers are dependent on the benefits/disbenefits of different driver groups. The network benefits arise when the benefits to incident drivers outweigh the disbenefits to non-incident drivers. The journey time savings of network drivers and the correspondent NPR values are illustrated in **Error! Reference source not found.**. In the Redbridge Causeway, the total journey time-savings of network drivers were 762 veh-h when 28% of drivers diverted in Table 7.4. This represents a recovery of 16% of the additional journey time caused by the incident. The maximum journey timesaving of network drivers would have occurred when 50% of drivers diverted (compared to the optimal diversion level of 90% for the incident drivers), with the values of journey time-savings and NPR being 884 veh-h and 19% respectively.

In the Northam Road scenario, the total journey time-savings of network drivers was negative, which indicated that there was no benefits when 42% of drivers diverted. The maximum journey time-savings of network drivers would have reached when 20% of drivers diverted (compared to the optimal diversion level of 60% for the incident drivers), with the values of journey time-savings and NPR being 119.7 veh-h and 3.3% respectively. There were no network benefits from VMS when over 33% of the drivers diverted, although the incident drivers still benefited.

In the Onslow Road scenario, the total journey time-savings of network drivers was 226.1 veh-h when 6.1% of drivers diverted. This represented a recovery of 39% of the additional time caused by the incident. The maximum journey time-savings of network drivers would have been reached when 30% of drivers diverted (compared to the optimal diversion level of 50% for the incident drivers), with the values of journey time-savings and NPR being 265.3 veh-h and 45% respectively. There were no network benefits from VMS when over 70% of the drivers diverted, although incident drivers still benefited.

Table 7.4 Network benefits and NPR for the three incident scenarios.

		A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
Observed	Diversion rate (%)	28	42	6.1
	Network journey time savings (veh-h)	762	-195	226.1
	Network Percentage Recovery (%)	16	-0.05	39
Optimal	Optimal diversion rate (%)	50	20	30
	Network journey time savings (veh-h)	884.8	119.7	265.3
	Network Percentage Recovery (%)	19	3.3	45

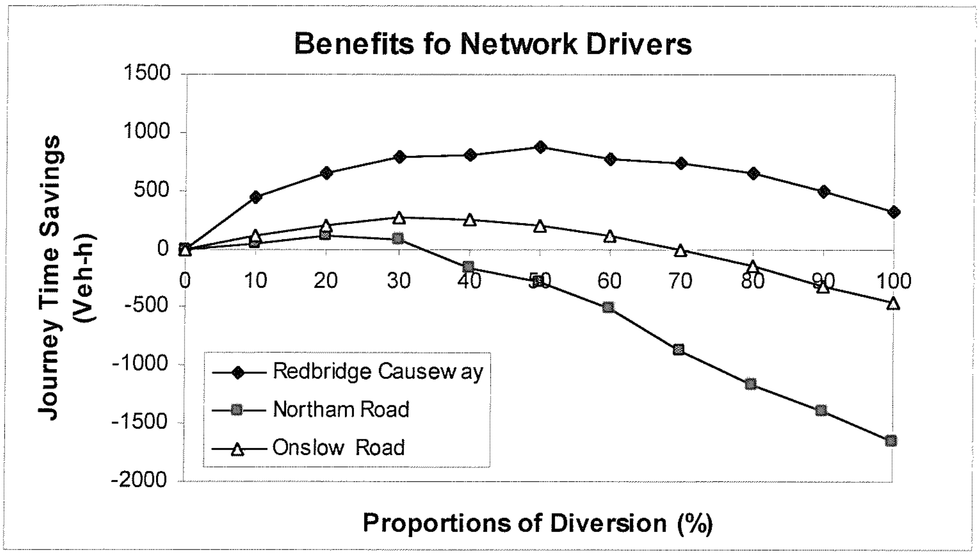

Figure 7.3 Journey time savings for network drivers

7.3 Travel speed

In the Redbridge Causeway scenario, the average travel speed of the network drivers increased by 3.8%, from 44.3 km/h to 46.0 km/ and the average speed of the incident drivers increased by 25.2%, from 11.9 km/h to 14.9 km/h (Table 7.5). In the Northam Road scenario, the average speed of the network drivers decreased by 0.6%, from 46.8 km/h to 46.5 km/h, whilst the average speed of incident drivers increased by 49.3%, from 7.5 km/h to 11.2 km/h. In the Onslow Road scenario, the average speed of network drivers increased from 55.2 km/h to 55.5 km/h and the average speed of incident drivers increased by 21.1%, from 16.6 km/h to 20.1 km/h. Comparing the speed between network drivers and incident drivers indicates that VMS has limited impacts on overall network speed. However, VMS information can substantially reduce congestion to, and increase the speed of incident drivers (Figure 7.4 and Figure 7.5).

Table 7.5 Average travel speeds of incident and network drivers

		A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
Average Speed of Network Drivers (km/h)	Without VMS	44.3	46.8	55.2
	With VMS	46.0	46.5	55.5
Average Speed of Incident Drivers (km/h)	Without VMS	11.9	7.5	16.6
	With VMS	14.9	11.2	20.1

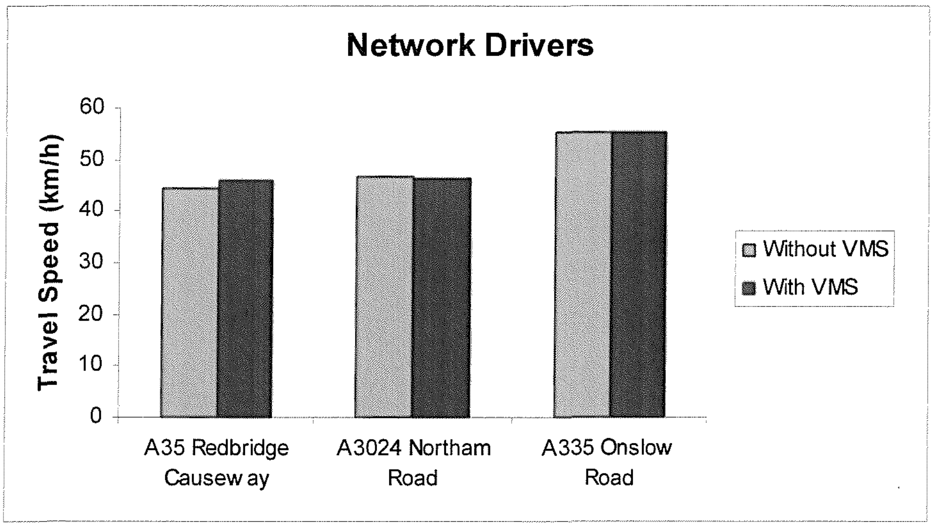

Figure 7.4 Average travel speed of network drivers

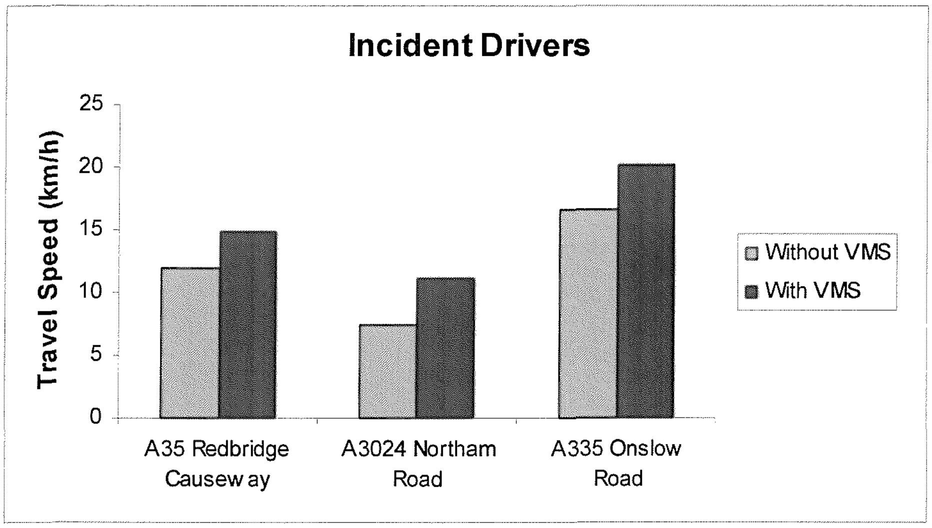

Figure 7.5 Average travel speed of incident drivers

7.4 Congestion

The congestion index (i.e. the ratio of journey time to cruise time) was used to assess the impacts of VMS on congestion. In the Redbridge Causeway scenario, the network congestion index reduced from 1.69 to 1.63 (Table 7.6) when 28% of drivers diverted, which was the largest reduction in the three scenarios studied. The corresponding changes in network congestion index were from 1.60 to 1.61 when 42% of drivers diverted in the Northam Road scenario and from 1.36 to 1.35 when 6.1% of drivers diverted in the Onslow Road scenarios.

Unlike the other two incident scenarios, the network congestion index in the Northam Road scenario increased from 1.60 to 1.61 when 42% of drivers diverted. One of the main reasons for this was that there were no suitable alternative routes when the incident occurred on Northam Road westbound. Because of the Itchen River, most westbound drivers had to cross the river by using bridges (Itchen Bridge, Northam Bridge and St Deny's Bridge). During the AM peak period, traffic on these bridges all became hevay; there were little spare capacity to accommodate diversion traffic. Diversion made traffic on these routes even more congested.

Table 7.6 Network congestion index

	A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
Without VMS	1.69	1.60	1.36
With VMS	1.63	1.61	1.35

7.5 Travel distance

Network travel distances increased in all of these three scenarios tested (Table 7.7). In the Redbridge Causeway scenario, the network travel distance increased by 5289 km, from 992129 km to 997418 km, which was the largest in the three scenarios studied. In the Northam Road scenario, the network travel distance increased by 3783 km, from 940961 km to 944744 km. In the Onslow Road scenario, the network travel distance increased by 25 km from 940963 to 940988 km, which was the smallest in the three scenarios.

In the Redbridge Causeway scenario, the travel distance of each diverting driver increased by 5.10 km; The travel distances of each diverting driver increased by 3.28 km and 0.31 km in the Northam Road and Onslow Road scenarios (Figure 7.6). In Redbridge Causeway scenario, 28% drivers diverted although there was an extra distance of 5.10 km to cover, compared with 6.1% of drivers diverted with 0.31 km extra distance in Onslow Road scenario. These results illustrate that distance is not the only factor for drivers to consider when making route choice decisions.

Table 7.7 Travel distance

	A35 Redbridge Causeway (27/03/00)	A3024 Northam Road (28/11/00)	A335 Onslow Road (16/08/99)
Without VMS (veh-km)	992129	940960	940963
With VMS (veh-km)	997418	944744	940988

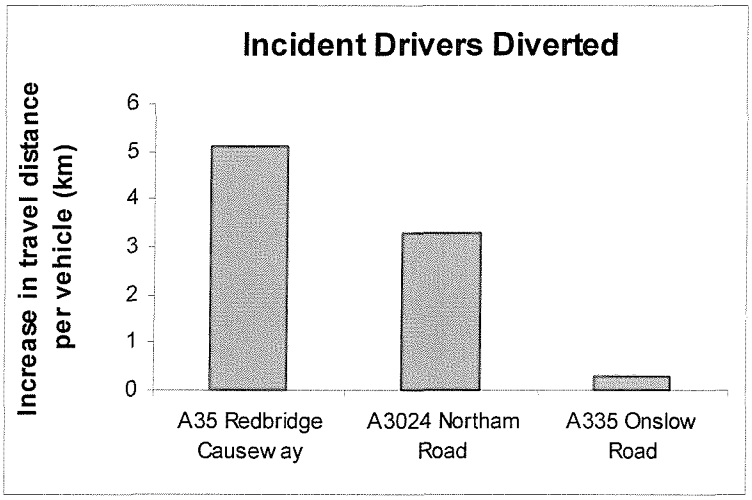

Figure 7.6 Increase in travel distance for incident drivers

From the point of view of distance, diversion has some negative impacts on those drivers who diverted to alternative routes. Such disbenefits depend on the distance between diversion and incident routes.

7.6 Conclusions

Journey timesavings, speed, congestion index and travel distance have been used to assess the impacts of VMS information on network traffic efficiency (the comprehensive modelling results for the three incident cases are listed in Table 7.8, Table 7.9 and Table 7.10). Based on the modelling results, the following conclusions can be draw about the impacts of VMS on network traffic efficiency:

- In general, incident drivers benefit, whilst non-incident drivers disbenefit from VMS in terms of journey time-savings. The network benefits arise when the journey time savings of incident drivers outweigh the disbenefits of non-incident drivers. The distribution of the benefits of VMS must be considered carefully. The small network benefits might be the result of incident drivers benefiting substantially, whilst non-incident drivers disbenfit substantially as well (e.g. the Northam Road scenario). Diversion routes and congestion levels have significant impacts on the journey time-savings of both incident and non-incident drivers.

- The results of speed indicated that VMS has limited impacts on overall network speed, although, VMS information can substantially reduce the congestion locally.

- Diversion can cause significant increases in distance travelled which is dependent on the diversion routes used and the number of diverting drivers.

- In the assessments, average diversion rates were used for each incident scenario, in which it was assumed that there were no changes in diversion rates during the incident/VMS. This might not be true in reality. As observed in the incident scenarios, the diversion rates were not constant. However, like most aggregate approach based models, the RGCONTRAM model cannot model changes in diversion rates during the same time slice.

Table 7.8 Modelling results for the A35 Redbridge Causeway scenario (27/03/2000)

Proportions of Diversion (%)	0	10	20	30	40	50	60	70	80	90	100
Freemoving time (veh-h)	13253.1	13271.3	13290.4	13309.3	13327.4	13346.2	13368.7	13390.9	13417.2	13450.8	-220.4
Timesavings in freemoving (veh-h)	.	-18.2	-37.3	-56.2	-74.3	-93.1	-115.6	-137.8	-164.1	-197.7	1677.4
Flow delay time (veh-h)	1502.8	1523.2	1525.8	1565.7	1605.1	1626.9	1626.5	1648.9	1649.6	1662	-174.6
Timesavings in flow delay time (veh-h)	.	-20.4	-23	-62.9	-102.3	-124.1	-123.7	-146.1	-146.8	-159.2	6956.5
Queuing time (veh-h)	7664.6	7186.9	6958.4	6754.8	6686.3	6562.7	6651.8	6635.2	6705.8	6814.3	708.1
Timesavings in queuing (veh-h)	.	477.7	706.2	909.8	978.3	1101.9	1012.8	1029.4	958.8	850.3	22107.4
Total journey time (veh-h)	22420.6	21981.4	21774.5	21629.9	21618.8	21535.8	21647.1	21675	21772.6	21927.1	313.2
Journey timesavings of total journey (Veh-h)	0	439.2	646.1	790.7	801.8	884.8	773.5	745.6	648	493.5	1337
Journey time of vehicles passing VMS and incident (veh-h)	3199.3	2870.6	2561.9	2221.9	1895.1	1646.3	1376.3	1128	925.4	705.6	4267.7
Journey time of vehicles passing incident but not VMS (veh-h)	3498.8	3409.6	3332.9	3361.6	3453.5	3499.9	3624.9	3771	3919.8	4101.1	1881.7
Benefits of incident drivers (veh-h)	.	417.9	803.3	1114.6	1349.5	1551.9	1696.9	1799.1	1852.9	1891.4	-1568.5
Benefits of non-incident drivers (veh-h)	.	21.3	-157.2	-323.9	-547.7	-667.1	-923.4	-1053.5	-1204.9	-1397.9	-1568.5
Journey time of vehicles passing VMS but not incident (veh-h)	333.3	350.1	392.1	462.6	566.3	700.1	827.6	969.3	1090.1	1234.5	1369.7
Journey time of vehicles passing neither VMS nor incident (veh-h)	15389	15351.1	15487.7	15583.8	15704	15689.5	15818.4	15806.8	15837.4	15885.9	15921.4
Congestion index	1.69	1.66	1.64	1.63	1.62	1.61	1.62	1.62	1.62	1.63	1.64
Distance travelled (veh-km)	992129.3	993957.2	995875.3	997803.9	999689.1	1601.1	3834.5	6064.6	8633.4	11989	14184.9
Distance of unfamiliar drivers (veh-km)	222450.4	222450.3	222450.4	222450.4	222450.4	222450.5	222450.4	222450.2	222450.2	222450.3	222450.2

(Continued)

Proportions of Diversion (%)	0	10	20	30	40	50	60	70	80	90	100
Distance of vehicles passing VMS and incident (km)	38221.8	35732.5	33179.5	30647.5	28420.7	26256.2	23854.2	21607.5	19247.3	16471.4	14556.5
Distance of vehicles passing VMS but not incident (km)	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3
Distance of vehicles passing incident but not VMS (km)	40845	45163.6	49636.3	54092.9	58207.2	62280.9	66919.2	71387.5	76313.3	82445.8	86553.3
Distance of vehicles passing neither VMS nor incident (km)	892467.3	892468.6	892467.4	892465.5	892464.2	892465.4	892462.1	892463.6	892463.8	892465	892463.4
Overall network speed (km/h)	44.3	45.2	45.7	46.1	46.2	46.5	46.4	46.4	46.3	46.2	45.9
Speed of unfamiliar drivers (km/h)	43.6	44.1	44.2	44.3	44.5	44.7	44.8	45.2	45.4	45.6	46
Total final queues (veh)	23349	22938.2	24822.9	24920	25914.8	26254.3	27982	27439	28219.8	28359.4	28111.1
Total stops	513092	513666	519533	526349	527983	530677	535021	529607	535572	531796	532182
Percentage of stoped vehicles (%)	22.3	22.3	22.6	22.8	22.9	23	23.1	22.9	23.1	22.9	22.9
Network Percentage Recovery (%)	0.00	0.09	0.14	0.17	0.17	0.19	0.16	0.16	0.14	0.10	0.07
Speed of Diverting Drivers (km/h)	11.95	12.45	12.95	13.79	15.00	15.95	17.33	19.16	20.80	23.34	26.53
Speed of incident drivers (km/h)	11.80436	12.88113	14.04896	15.17693	16.19637	17.20436	18.15032	18.98245	19.72274	20.57903	20.99282

Table 7.9 Modelling results for the A3024 Northam Road scenario (28/11/00)

Proportions of Diversion (%)	0	10	20	30	40	50	60	70	80	90	100
Freemoving time (veh-h)	12582.9	12598.7	12619.9	12632.7	12653.6	12672	12688.9	12704.2	12715.4	12731.4	12743.4
Timesavings in freemoving (veh-h)	.	-15.8	-37	-49.8	-70.7	-89.1	-106	-121.3	-132.5	-148.5	-160.5
Flow delay time (veh-h)	1378.7	1396.8	1414.6	1421.8	1427.6	1442.7	1451.1	1455.7	1458.8	1468	1479.8
Timesavings in flow delay time (veh-h)	.	-18.1	-35.9	-43.1	-48.9	-64	-72.4	-77	-80.1	-89.3	-101.1
Queuing time (veh-h)	6164	6086.7	5971.4	6000.1	6215.6	6297.9	6487.1	6836.9	7111.1	7322.8	7560.8
Timesavings in queuing (veh-h)	.	77.3	192.6	163.9	-51.6	-133.9	-323.1	-672.9	-947.1	-1158.8	-1396.8
Total journey time (veh-h)	20125.6	20082.2	20005.9	20054.6	20296.8	20412.6	20627.2	20996.8	21285.3	21522.2	21784.1
Journey timesavings of total journey (Veh-h)	0	43.4	119.7	71	-171.2	-287	-501.6	-871.2	-1159.7	-1396.6	-1658.5
Journey time of vehicles passing VMS and incident (veh-h)	3456.3	3052.8	2470.4	2156.7	1802.1	1414.5	1165.5	945.4	769.7	604.7	485.8
Journey time of vehicles passing incident but not VMS (veh-h)	1254.1	1308.6	1492.1	1548.4	1727.3	1968.5	2144.8	2388.2	2582.5	2801.9	2983.8
Benefits of incident drivers (veh-h)	.	349	747.9	1005.3	1181	1327.4	1400.1	1376.8	1358.2	1303.8	1240.8
Benefits of non-incident drivers (veh-h)	.	-305.6	-628.2	-934.3	-1352.2	-1614.4	-1901.7	-2248	-2517.9	-2700.4	-2899.3
Journey time of vehicles passing VMS but not incident (veh-h)	480.1	484.5	485	496.2	501.6	502	514.1	518.3	528.8	531.6	538.4
Journey time of vehicles passing neither VMS nor incident (veh-h)	14935	15236.2	15558.5	15853.2	16265.7	16527.6	16802.9	17144.8	17404.3	17584	17776.1
Congestion index	1.6	1.59	1.59	1.59	1.6	1.61	1.63	1.65	1.67	1.69	1.71
Distance travelled (veh-km)	940960.8	941789.2	942853.8	943516.4	944571	945435.2	946328.2	947182.9	947820.6	948619.9	949323.9
Distance of unfamiliar drivers (veh-km)	210639.4	210639.5	210639.4	210639.6	210639.5	210639.2	210639.6	210639.6	210639.5	210639.6	210639.4

(Continued)

Proportions of Diversion (%)	0	10	20	30	40	50	60	70	80	90	100
Distance of vehicles passing VMS and incident (km)	27066.1	24842.3	22295.8	20621.4	18672.2	16444.8	14791.2	13351.5	12025.2	10669.6	9703.3
Distance of vehicles passing VMS but not incident (km)	25251.4	25251.4	25251.4	25251.4	25251.4	25251.4	25251.4	25251.4	25251.4	25251.4	25251.4
Distance of vehicles passing incident but not VMS (km)	8275	11331.7	14944	17286.8	20290	23383.1	25931.5	28230.3	30197.7	32350.7	34023.7
Distance of vehicles passing neither VMS nor incident (km)	880317.2	880318.8	880318.1	880317.1	880316.9	880315.7	880317.8	880314.8	880313.2	880314.9	880313.2
Overall network speed (km/h)	46.8	46.9	47.1	47	46.5	46.3	45.9	45.1	44.5	44.1	43.6
Speed of unfamiliar drivers (km/h)	45.3	44.9	44.8	44.6	44.2	44.3	44.1	43.8	43.7	43.8	43.8
Total final queues (veh)	19346.9	20640.5	21366.4	23140.7	24811	25554.6	26455.7	27778.8	28664.7	29285.4	29940.1
Total stops	479958	485464	488103	494396	500108	500481	501660	505524	507213	509103	510878
Percentage of stoped vehicles (%)	21.9	22.1	22.1	22.4	22.6	22.6	22.6	22.7	22.7	22.8	22.9
Network Percentage Recovery (%)	0.000	0.012	0.033	0.019	-0.047	-0.079	-0.137	-0.239	-0.318	-0.383	-0.454
Speed of Diverting Drivers (km/h)	7.83	8.14	9.03	9.56	10.36	11.63	12.69	14.12	15.62	17.64	19.97
Speed of incident drivers (km/h)	7.502781	8.294126	9.398057	10.23136	11.03933	11.77295	12.30182	12.47354	12.59558	12.62852	12.60289

Table 7.10 Modelling results for the A335 Onslow Road scenario (16/08/99)

Proportions of Diversion (%)	0	10	20	30	40	50	60	70	80	90	100
Freemoving time (veh-h)	12582.9	12584.1	12586	12589	12590	12590.9	12590	12593.4	12591.8	12589.9	12592
Timesavings in freemoving (veh-h)	.	-1.2	-3.1	-6.1	-7.1	-8	-7.1	-10.5	-8.9	-7	-9.1
Flow delay time (veh-h)	1391.2	1387.7	1387	1381.3	1383.8	1361.4	1371.9	1367.8	1366.6	1365.9	1360.4
Timesavings in flow delay time (veh-h)	.	3.5	4.2	9.9	7.4	29.8	19.3	23.4	24.6	25.3	30.8
Queuing time (veh-h)	3511.9	3379.7	3247.9	3195.7	3475.7	4234.1	4071.6	4756.7	5177.7	4995.2	5771.5
Timesavings in queuing (veh-h)	.	132.2	264	316.2	36.2	-722.2	-559.7	-1244.8	-1665.8	-1483.3	-2259.6
Total journey time (veh-h)	17486	17351.6	17220.9	17166	17449.5	18186.4	18033.6	18717.9	19136.1	18950.9	19723.9
Journey timesavings of total journey (Veh-h)	0	134.4	265.1	320	36.5	-700.4	-547.6	-1231.9	-1650.1	-1464.9	-2237.9
Journey time of vehicles passing VMS and incident (veh-h)	801.3	679	540	428	351.5	546.1	395.5	443.2	793.8	460.6	617.7
Journey time of vehicles passing incident but not VMS (veh-h)	307.7	321.7	426.8	492.2	703.6	613.4	849.8	1064	819.5	1212.3	1287.5
Benefits of incident drivers (veh-h)	.	108.3	142.2	188.8	53.9	-50.5	-136.3	-398.2	-504.3	-563.9	-796.2
Benefits of non-incident drivers (veh-h)	.	26.1	122.9	131.2	-17.4	-649.9	-411.3	-833.7	-1145.8	-901	-1441.7
Journey time of vehicles passing VMS but not incident (veh-h)	687	670.4	590.9	566.6	649.1	1086.8	930.8	1161.3	1501.2	1283.7	1598.7
Journey time of vehicles passing neither VMS nor incident (veh-h)	15690	15680.4	15663.2	15679.2	15745.3	15940	15857.5	16049.4	16021.6	15994.3	16220
Congestion index	1.39	1.38	1.37	1.36	1.39	1.44	1.43	1.49	1.52	1.51	1.57
Distance travelled (veh-km)	940952	941005.6	941094.9	941237.4	941280.2	941320.8	941272.1	941434.8	941362.1	941251.4	941358.9
Distance of unfamiliar drivers (veh-km)	11074.3	10192.9	9261	8510.2	7583.1	8043.2	6791.2	6398	7733.6	5702.9	5991.3

(Continued)

Proportions of Diversion (%)	0	10	20	30	40	50	60	70	80	90	100
Distance of vehicles passing VMS and incident (km)	38221.8	35732.5	33179.5	30647.5	28420.7	26256.2	23854.2	21607.5	19247.3	16471.4	14556.5
Distance of vehicles passing VMS but not incident (km)	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3	20564.3
Distance of vehicles passing incident but not VMS (km)	40845	45163.6	49636.3	54092.9	58207.2	62280.9	66919.2	71387.5	76313.3	82445.8	86553.3
Distance of vehicles passing neither VMS nor incident (km)	892467.3	892468.6	892467.4	892465.5	892464.2	892465.4	892462.1	892463.6	892463.8	892465	892463.4
Overall network speed (km/h)	44.3	45.2	45.7	46.1	46.2	46.5	46.4	46.4	46.3	46.2	45.9
Speed of unfamiliar drivers (km/h)	43.6	44.1	44.2	44.3	44.5	44.7	44.8	45.2	45.4	45.6	46
Total final queues (veh)	23349	22938.2	24822.9	24920	25914.8	26254.3	27982	27439	28219.8	28359.4	28111.1
Total stops	513092	513666	519533	526349	527983	530677	535021	529607	535572	531796	532182
Percentage of stoped vehicles (%)	22.3	22.3	22.6	22.8	22.9	23	23.1	22.9	23.1	22.9	22.9
Network Percentage Recovery (%)	0.00	0.09	0.14	0.17	0.17	0.19	0.16	0.16	0.14	0.10	0.07
Speed of Diverting Drivers (km/h)	11.95	12.45	12.95	13.79	15.00	15.95	17.33	19.16	20.80	23.34	26.53
Speed of incident drivers (km/h)	11.80436	12.88113	14.04896	15.17693	16.19637	17.20436	18.15032	18.98245	19.72274	20.57903	20.99282

8 Summary and Conclusions

The research described within this thesis concerns the routing effects of VMS in urban area using both network modelling and field measurements. The main findings from the research conducted and recommendations for future study are presented below.

8.1 Main findings

8.1.1 Main findings from modelling results

In this research, the routing effects of VMS have been studied by using the 'single-day' version RGCONTRAM model. The main contributing factors of VMS effects investigated include diversion levels, traffic demands, incident severities, incident durations, VMS durations, VMS starting time and ending time. The 'single-day' version RGCONTRAM model has been found very useful in studying VMS by which the network routing effects of VMS in coditions of varying incidents and VMS strategies can be explored. Based on the modelling results, the following conclusions can be drawn relating to the routing effects of VMS:

- The relative congestion level on incident routes to that on diversion routes is one of the key factors which determine the benefits of VMS. When diversion routes are less congested than incident routes (e.g. when no diversion or at initial stages of the diversion), implementing a VMS strategy can make drivers benefit from diversion because of the shorter journey time using diversion routes. However, when congestion levels on diversion routes are equal to or higher than those on incident routes (e.g. minor incidents and large number of vehicles being diverted to the alternative routes), there is very little chance for drivers to benefit from diversion by VMS.

- In general, incident drivers benefit from diversion, including those incident drivers who do not divert because of the reduced congestion on the incident route. Non-incident drivers disbenefit from diversion especially those travelling on the main diversion routes. Network benefits arise when the benefits to incident drivers outweigh the disbenefits to non-incident drivers.

- Traffic demand is one of the most important factors which influence the routing effects of VMS. For given network and incident, there is more congestion on incident routes and less spare capacity on diversion routes when at high demand; however, there is less congestion on incident routes and more spare capacity on diversion routes when at low demand. So, there is clearly a window of traffic demands within which the maximum network benefits may be achieved from deploying the appropriate VMS strategies.

- Incident severity and duration are the two elements which have key influences on the congestion levels on incident routes. When a minor and short incident occurs and there is little queuing on the incident route, too much diversion may result in the remaining capacity of the incident link not being fully used. However, when a more severe and longer incident occurs, the increases in queuing caused by the incident increases the potential benefits of diversion. This highlights the importance of incident characteristics in strategy decisions. When the incident is severe or longer, there is large potential of network journey time-savings from diversion. However, when a minor or short incident occurs, implementing a VMS strategy achieves very little or no network benefits and therefore implementation is not considered worthwhile.

- VMS duration is one of the most important factors which influence influence the number of drivers who receive VMS information. Both delaying VMS activation and extending VMS duration beyond incidents can increase/decrease the benefits of diversion. For incidents causing significant queuing, early detection and VMS activation is vital for increasing the benefits of VMS. Any delays mean that the benefits of the VMS are reduced.

- The benefits of VMS have been derived by comparing journey times in the incident scenario with those in the base scenario, i.e. "do nothing" scenarios in which it is assumed that no diversion occurs. This is not always true in reality. Some drivers might divert when they encounter additional queues on their original route (although such routing decisions might take longer time than the informed decisions using VMS information). Because the current knowledge of drivers' routing responses to congestion has not reached to the stage in which an accurate estimation can be made, no pre-defined value has been made for drivers' diversion in response to congestion in this modelling. Therefore, the modelling results of VMS benefits might be overestimated by the extent to which some drivers divert because of observed congestion. This will be greatest when the traffic and severity are greatest.

- The congestion level caused by incidents is one of the most important factors for operators to consider when making decisions on VMS strategies. Incident severity, incident duration, incident location, traffic demand and diversion levels et al all have some influences on such congestion. However, it is difficult to establish the effects of individual factors in isolation, because these factors interact with each other in reality.

- All of the modelling results are based on the incident scenarios in Southampton urban areas. Because there is no special parameters used in modelling these incident scenarios, most results about the trends and the relationships between VMS effects and their factors should be transferred referred for other VMS studies. However, the values of the optimum diversion levels, optimum VMS durations for each incident are site specific and can not be transferred directly to other VMS studies.

8.1.2 Main findings from measured results

Driver's actual diversion responses to VMS were investigated by analysing detector data, incident and VMS logs concerning incident cases occurring on the A35, A3024, A33 and A335. Both early and late diversions at VMS were found, which are very important for assessing the routing effects of VMS. The following conclusions can be drawn based on the incident cases studied:

- Detector data have been found very useful in studying the routing effects of VMS. The analysis of detector data can enable a post-mortem evaluation of an incident scenario to be replayed. In addition to the standard traffic flow data, it is important to include others such as speed and occupancy to obtain better understanding. The methods used in this study were found useful, especially in obtaining quantitative assessments of traffic behaviour in conditions of traffic information.

- There is evidence to indicate that VMS alone can significantly affect a driver's route decision. Early diversion is a good indictor of such effects. According to detector data, between 0 and 34% drivers made early diversions. This varies with the number and location of viable diversion routes, and the contents of the VMS messages.

- Late diversions have been widely found in most incident cases studied where drivers diverted after having observed the queues. The high rates of late diversion indicated that drivers were more likely to divert after obtaining visual confirmation of the observed queues caused by the incidents. However, it is not clear that how much VMS message contribute to such late diversion because of no data is available for comparing diversion before and after VMS instalment.

- In the incident scenarios of the A35 Redbridge Causeway, the two VMS signs of H01, H02 were of the same site and operated using the same strategies, however, diversion rates varied with VMS locations. This indicates that driver's diversion responses to VMS are dependent not only on the messages they received, but also on the conditions such as relative congestion levels between incident and diversion routes; easiness to access to diversion routes; driver's network knowledge and experiences of similar situations.

- The results of the incident case studies show that the higher the number of diversion routes between VMS ('decision points') and incident locations, the lower the early diversion rates. For example, when incidents occurred on the A35 Redbridge Causeway eastbound, up to 34% drivers were found made early diversion in which there is only one major diversion route. However, when the incidents occurred on the A33, A335 and A3024, most of the observed early diversion rates were in the range of 0-10% in which there were several viable alternatives available for diversion. When there are several alternative routes available between decision points and incident locations, drivers do not need to worry about getting stuck in the queues if they miss the first diversion route, they can divert later using other routes when encountering unexpected queues on their normal routes.

- As indicated by the observed results that there is a close relationship between diversion behaviour and the strength of the message. Currently, 'Short Delays', 'Delays' and 'Long Delays' are the main messages regarding the congestion levels during incidents. However, it is not clear how drivers perceive the difference between these three qualitative messages. There could be a lot differences in drivers' interpretation to such messages, especially the "Delays" and Long Delays" messages. Taking the incident location on A35 Redbridge Causeway inbound for an example, the "Delay" message could mean a queue length bewteen 84 and 518 vehicles (from Redbridge Cuaseway to Rushington roundabout), the "Long Delays" message could mean a queue length between 518 and 805 vehicles (from Redbridge Causeway to Hunters Hill roundabout). This suggests that quantitative information of delays or journey times are needed to increase the effectiveness of VMS.

- Questionnaires were conducted to those users of A33, A35, A335 and A3024 in Southampton in (Richard et al, 1998). According to the survey results, 58% of drivers regarded VMS either "very useful" or "quite useful"; 49% of drivers said that VMS information "often" or "sometimes" affected their route choice. However, there were no results of early diversion rates from this survey for comparision with observed results in Southampton. According to the stated preference survey results in London (Thompson et al, 1998), 21% of drivers made early diversion with "Delay" message and 25% with "Long Delay" message. These stated early diversion rates are higher than those observed in Southampton for the same type of messages (most within the range of 0-10%).

8.2 Recommendations for future study

Southampton provides a very good environment for studying drivers' route choice behaviours with VMS because of the large coverage of VMS, good traffic monitoring facilities and the research results having been achieved. However, understanding driver's routing behaviours with traffic information is a very difficult issue, there are many factors which have influences on driver's route choice decisions. It is a great challenge to fully understand driver's actual diversion responses and their network routing effects. Based on this research, the recommendations for future studies are:

- Long-term studies of diversion impacts of VMS conducted through the analysis of automatic traffic data and message logs are required to strength the conclusion from incident case studies to obtain a greater understanding of VMS effects. This understanding is a vital component in the development of information provision strategies.

- More detectors at strategic locations are required to better study the drivers' routing responses to VMS, e.g. on the A27 (one of the main diversion routes for incidents on the A3024). Detector locations are very important to observe drivers' diversion responses to

VMS information. Ideally, detectors should be on the first link after each decision points on both incident and diversion routes. To study drivers' diversion responses to VMS, traffic data both before and after decision points are equally important.

- Because of the day-to-day variation in traffic flow, it is difficult to identify diversion traffic from normal traffic when diversion levels are at low levels. Long term studies of detected flows aided by other methods such as CCTV monitoring or registration plate surveys might be more effective to identify driver's actual diversion responses to VMS.

- The provision of quantitative information on the VMS regarding status of congestion, such as delay, queue length or journey time, could have better help drivers to make route choice decisions. The meanings of the 'Short Delays', 'Delays' and 'Long Delays' are perhaps too vague, and it is difficult for operators and drivers to appreciate the differences between them.

- In Southampton apart from VMS, radio broadcasting is another major source which provides online traffic information to drivers. In addition, static signs are sometimes used for large planned roadworks or other events. All of these sources could have some influence on driver's route choice decisions. Further studies are needed to know the contributions of each information source to driver's route choice decisions, e.g. by stated or revealed preference surveys.

- In the study period, 174 accidents occurred on Motorway and trunk roads around Southampton, which accounted for 61% of the total accidents. Most motorway accidents involved serious casualties and damage to property which caused long delays to traffic. This should be studied in more detail.

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Appendix A: Statistic and test results

1. Roadworks on Redbridge Causeway inbound (27/03/2000)

The number of vehicles passing detector D14112 (veh)

	07:00-07:30	07:30-11:15	11:15-11:45	11:45-17:00	17:00-17:30
20/03/00	416	2555	240	2663	272
21/03/00	440	2607	232	2703	264
22/03/00	424	2283	240	2568	272
24/03/00	432	2572	288	2879	248
27/03/00	371	883	167	2492	212
28/03/00	452	2219	264	2475	280
29/03/00	504	2384	256	2603	280
30/03/00	480	2400	240	2631	248
31/03/00	456	2492	264	2887	248

One-Sample Statistics (07:00-07:30)

	N	Mean	Std. Deviation	Std. Error Mean
D14112	8	450.5000	29.5442	10.4454

One-Sample Test (07:00-07:30)

	Test Value = 371					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
D14112	7.611	7	.000	79.5000	54.8005	104.1995

One-Sample Statistics (07:30-11:15)

	N	Mean	Std. Deviation	Std. Error Mean
D14112	8	2439.0000	141.1484	49.9035

One-Sample Test (07:30-11:15)

	Test Value = 883					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
D14112	31.180	7	.000	1556.0000	1437.9970	1674.0030

One-Sample Statistics (11:15-11:45)

	N	Mean	Std. Deviation	Std. Error Mean
D14112	8	253.0000	18.6088	6.5792

One-Sample Test (11:15:17:00)

	Test Value = 167					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
D14112	13.072	7	.000	86.0000	70.4427	101.5573

One-Sample Statistics (11:45-17:00)

	N	Mean	Std. Deviation	Std. Error Mean
D14112	8	2676.1250	144.4432	51.0684

One-Sample Test (11:45-17:00)

	Test Value = 2492					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
D14112	3.605	7	.009	184.1250	63.3675	304.8825

One-Sample Statistics (17:00-17:30)

	N	Mean	Std. Deviation	Std. Error Mean
D14112	8	264.0000	14.1825	5.0143

One-Sample Test (17:00-17:30)

	Test Value = 212					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
D14112	10.370	7	.000	52.0000	40.1431	63.8569

2. Accident on The Avenue junction with Burgess Road (10/11/00)

Traffic during the time period of 10:00-10:40 AM (veh)

	N03214A&K	N05911D	N03224M	N03224F&G	N03111E	N01311E	N03131J
24/10/00	933	231	1150	469	604	365	115
26/10/00	698	206	862	769	419	339	118
27/10/00	1006	245	1265	1124	609	411	125
30/10/00	909	244	1068	1114	331	566	198
31/10/00	866	215	1067	930	509	397	127
01/11/00	905	214	1187	993	571	404	122
02/11/00	857	315	1150	1131	193	596	185
03/11/00	922	220	1155	1025	584	383	147
06/11/00	861	234	1071	972	548	377	132
07/11/00	883	206	1110	985	570	386	119
08/11/00	970	258	1191	1064	606	393	135
09/11/00	995	209	1261	1111	651	405	135
10/11/00	870	284	1047	979	121	682	166
13/11/00	856	217	488	937	537	388	138
14/11/00	951	243	1186	984	506	466	125
15/11/00	889	231	1050	986	531	387	124
16/11/00	904	273	1148	984	555	407	102
20/11/00	837	217	1048	972	544	355	115
21/11/00	910	285	1138	1020	589	384	129
22/11/00	886	247	1130	987	592	399	179
23/11/00	845	221	1204	1049	608	399	159
24/11/00	843	241	1203	1133	611	415	145

(i) Traffic at N03214A&K

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N03214AK	20	901.4000	49.6455	11.1011

One-Sample Test

	Test Value = 870					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N03014AK	2.829	19	.011	31.4000	8.1652	54.6348

(ii) Traffic at N05911D

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N05911D	21	236.7619	27.8692	6.0816

One-Sample Test

	Test Value = 284					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N05911D	-7.767	20	.000	-47.2381	-59.9240	-34.5522

(iii) Traffic at N03111E

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N03111E	18	573.6111	39.3164	9.2670

One-Sample Test

	Test Value = 121					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N03111E	48.841	17	.000	452.6111	433.0595	472.1627

(iv) Traffic at N01311E

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N01311E	19	392.6316	26.2196	6.0152

One-Sample Test

	Test Value = 682					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N01311E	-48.106	18	.000	-289.3684	-302.0059	-276.7310

(v) Traffic at N03131J

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N03131J	21	136.8571	24.6927	5.3834

One-Sample Test

	Test Value = 166					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N03131J	-5.408	20	.000	-29.1429	-40.3828	-17.9029

3. Roadworks on A3024 Northam Road inbound (28/11/00)

Traffic at N11121F (veh)

	07:15-07:50	07:50-09:00	09:00-10:40
01/11/00	474	988	1093
02/11/00	457	879	1275
03/11/00	468	976	1160
06/11/00	382	962	1357
07/11/00	498	900	1177
08/11/00	528	938	1076
09/11/00	514	1022	1192
10/11/00	0	623	1155
13/11/00	473	992	1100
14/11/00	113	502	1195
15/11/00	508	960	1193
16/11/00	277	1003	1149
17/11/00	0	0	0
20/11/00	0	741	998
21/11/00	432	934	1119
22/11/00	482	988	1093

23/11/00	462	912	1119
24/11/00	480	958	1129
27/11/00	474	1004	1047
28/11/00	451	905	1100

One-Sample Statistics (07:15-07:50)

	N	Mean	Std. Deviation	Std. Error Mean
N11121F	14	477.8571	27.0750	7.2361

One-Sample Test (07:15-07:50)

	Test Value = 451					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N11121F	3.712	13	.003	26.8571	11.2245	42.4898

One-Sample Statistics (07:50-09:00)

	N	Mean	Std. Deviation	Std. Error Mean
N11121F	15	961.0667	41.4840	10.7111

One-Sample Test (07:50-09:00)

	Test Value = 905					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N11121F	5.234	14	.000	56.0667	33.0936	79.0398

One-Sample Statistics (09:00-10:40)

	N	Mean	Std. Deviation	Std. Error Mean
N11121F	17	1133.5294	65.2190	15.8179

One-Sample Test (09:00-10:40)

	Test Value = 1100					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N11121F	2.120	16	.050	33.5294	-3.09E-03	67.0619

4. Roadworks on the A335 Onslow Road inbound (16/08/99)

Traffic during time period of 07:00-09:30 (veh)

	N05151A&K	N05121G&H	N05141G	N06241A	N06211E	N06231A
02/08/99	3524	2000	2500	2921	1124	1413
03/08/99	3515	2018	2559	2994	1147	1474
04/08/99	3680	2093	2578	2935	1162	1490
05/08/99	3505	1922	2490	2825	1090	1430
06/08/99	3492	1997	2463	2904	1073	1496
10/08/99	3528	1992	2461	2900	1065	1426
11/08/99	3402	1939	2393	2842	1086	1370
12/08/99	3507	2005	2455	2850	1101	1445

13/08/99	3527	2013	2439	2791	1137	1375
16/08/99	3543	2024	2423	2908	1197	705
17/08/99	3618	2102	2302	2641	2328	520
18/08/99	3630	2058	2343	2569		622
19/08/99	3609	2137	2315	2615		595

(i) Traffic at N05151A&K

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N05151AK	9	3520.0000	71.4633	23.8211

One-Sample Test

	Test Value = 3543					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N05151AK	-.966	8	.363	-23.0000	-77.9315	31.9315

(ii) Traffic at N05121G&H

One-Sample Test

	Test Value = 2024					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N05121GH	-1.621	8	.144	-26.3333	-63.7896	11.1230

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N05121GH	9	1997.6667	48.7288	16.2429

(iii) Traffic at N05141G

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N05141G	9	2482.0000	57.9159	19.3053

One-Sample Test

	Test Value = 2423					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
N05141G	3.056	8	.016	59.0000	14.4819	103.5181

(iv) Traffic at N06241A

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N06241A	9	2884.6667	63.0198	21.0066

One-Sample Test

	Test Value = 2908					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N06241A	-1.111	8	.299	-23.3333	-71.7747	25.1080

(v) Traffic at N06211E

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N06211E	9	1109.4444	34.3624	11.4541

One-Sample Test

	Test Value = 1197					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N06211E	-7.644	8	.000	-87.5556	-113.9689	-61.1422

(vi) Traffic at N06231A

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
N06231A	9	1435.4444	45.7988	15.2663

One-Sample Test

	Test Value = 705					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
N06231A	47.847	8	.000	730.4444	695.2404	765.6485

Appendix B: VMS Strategy in Southampton

Strategy No	Strategy Name
111	BLANK DOWN SIGN
112	SIGN UNDER TEST
113	NO PROBLEM TO REPORT
114	ALL ROUTES FREE FLOWING
121	ACCIDENT SHORT DELAYS
122	ACCIDENT DELAYS
123	ACCIDENT LONG DELAYS
124	ACCIDENT DELAY EASING
125	ACCIDENT ROAD CLOSED
126	ACCIDENT CLEARED
127	ACCIDENT AVOID IF POSSIBLE
128	ACCIDENT USE DIVERSION
141	ROAD WORKS SHORT DELAYS
142	ROAD WORKS DELAYS
143	ROAD WORKS LONG DELAYS
144	ROAD WORKS DELAY EASING
145	ROAD WORKS ROAD CLOSED
146	ROAD WORKS FOLLOW DIVERSION
147	ROAD WORKS CLEARED
148	ROAD WORKS CLEARED FOR RUSH HOUR
161	BROKEN DOWN VEHICLE SHORT DELEAYS
162	BROKEN DOWN VEHICLE DELAYS
163	BROKEN DOWN VEHICLE LONG DELAYS

164	BROKEN DOWN VEHICLE DELAY EASING
165	BROKEN DOWN VEHICLE ROAD CLOSED
166	BROKEN DOWN VEHICLE CLEARED
167	BROKEN DOWN VEHICLE AVOID IF POSIIBLE
168	BROKEN DOWN VEHICLE USE DIVERSION

(Continued)

Strategy No	Strategy Name
182	SHED LOAD DELAYS
183	SHED LOAD LONG DELAYS
184	SHED LOAD DELAY EASING
185	SHED LOAD ROAD CLOSED
186	SHED LOAD CLEARED
187	SHED LOAD AVOID IF POSSOBLE
188	SHED LOAD USE DIVERSION
211	BURST WATER MIAN SHORT DELAYS
212	BURST WATER MAIN DELAYS
213	BURST WATER MAIN LONG DELAYS
214	BURST WATER MAIN DELAY EASING
215	BURST WATER MAIN ROAF CLOSED
216	BURST WATER MAIN CLEARED
217	BURST WATER MAIN AVOID IF POSSIBLE
218	BURST WATER MAIN USE DIVERSION
231	VEHICLE FIRE SHORT DELAYS
232	VEHICLE FIRE DELAYS
233	VEHICLE FIRE LONG DELAYS
234	VEHICLE FIRE DELAY EASING
235	VEHICLE FIRE ROAD CLOSED
236	VEHICLE FIRE CLEARED
237	VEHICLE FIRE AVOID IF POSSIBLE
238	VEHICLE FIRE USE DIVERSION
251	SEWER COLLAPSE SHORT DELAYS
252	SEWER COLLAPSE DELAYS
253	SEWER COLLAPSE LONG DELAYS
254	SEWER COLLAPSE DELAY EASING

(Continued)

Strategy No	Strategy Name
255	SEWER COLLAPSE ROAD CLOSED
256	SEWER COLLAPSE CLEARED
257	SEWER COLLAPSE AVOID IF POSSIBLE
258	SEWER COLLAPSE USE DIVERSION
271	FULE SPILLAGE SHORT DELAYS
272	FULE SPILLAGE DELAYS
273	FULE SPILLAGE LONG DELAYS
274	FULE SPILLAGE DELAY EASING
275	FULE SPILLAGE ROAD CLOSED
276	FULE SPILLAGE CLEARED
277	FULE SPILLAGE AVOID IF POSSIBLE
278	FULE SPILLAGE USE DIVERSION
291	FALLEN TREES SHORT DELAYS
292	FALLEN TREEES DELAYS
293	FALLEN TREES LONG DELAYS
294	FALLEN TREES DELAY EASING
295	FALEEN TREES ROAD CLOSED
296	FALLEN TREES CLEARED
297	FALLEN TREES AVOID IF POSSIBLE
298	FALLEN TREES USE DIVERSION
321	FALLEN POWER CABLES SHORT DELAEYS
322	FALLEN POWER CABLES DELAYS
323	FALLEN POWER CABLES LONG DELEYS
324	FALLEN POWER CABLES DELAY EASING
325	FALLEN POWER CABLES ROAD CLOSED
326	FALLEN POWER CABLES CLEARED
327	FALLEN POWER CABLES AVOID IF POSSIBLE
328	FALLEN POWER CABLES USE DIVERSION

Appendix C: Incident and VMS strategies used

Date	Road	Location	Cause	Severity Severity	Duration	Code1 Location	Time1 Time	Code2 Location	Time2 Time	Code3	Time3
23/08/99	A35	Redbridge Road	RTA	one lane blocked	1441-	85527	14:41				
03/09/99	A3024	Bittern Road West	RTA	one lane blocked	1237-1304	17121	12:37	17114	13:04		
04/09/99	A35	Redbridge Causeway	RTA	one lane blocked	1605-1631	84522	16:05	84514	16:31		
10/09/99	A35	Redbridge Road	RTA	one lane blocked	1745-1800	85522	17:45	85114	18:00		
14/09/99	A35	Mountbatten Way	RTA	one lane blocked	1232-	76521	12:32				
16/09/99	A35	M/batten Way	RTA	one lane blocked	0755-0837	76122	0755	76114	0846		
17/09/99	A35	Redbridge rd	RTA	one lane blocked	0902-0912	85122	0902	85127	0912	85114	0925
23/09/99	A3024	Bittern Road West	RTA	one lane blocked	0913-0922	17122	0913	17127	0922	17114	0931
24/09/99	A33	The Avenue	RTA	one lane blocked	1510-1534	96522	1510	96525		96121	
29/09/99	A35	Redbridge rd	RTA	one lane blocked	1750-1815	85522	1750	85514	1815		
30/09/99	A35	Redbridge rd	RTA	one lane blocked	1536-1545	85522	1536	85527	1545	85514	1550
08/10/99	A33	The Avenue/Lodge Road	RTA	one lane blocked	0736-0752	96122	0736	96114	0752		
13/10/99	A35	M/batten way/West Quay	RTA	one lane blocked	1806-1827	76122/76522	1806	76114	1827		
14/10/99	A35	Redbridge rd	RTA	one lane blocked	1600-1651	85522	1600	85514	1651		
28/10/99		Hamble lane	RTA	one lane blocked	0747-0810	82122	0747	82114	0810		
29/10/99	A35	Millbroke Road	RTA	Road clsodure	1609-1901	75523	1609	75522	1901		
02/11/99		Regent Pk Rd	RTA	one lane blocked	0700-0727	75122	0700	75114	0727		
04/11/99	A35	Redbridge Road	RTA	one lane blocked	1000-1029	85122	1000	85114	1029		
04/11/99	A335	Thomas Lewis/kent Rd	RTA	Road clsodure	0858-0950	97122	0926	97114	0950		
09/11/99	A3024	Bursledon Road/Coates	RTA	one lane blocked	1748-1758	20122	1748	20114	1758		
11/11/99		Itchin Bridge	RTA	one lane blocked	1550-1555	24542	1755				
11/11/99	A35	Redbridge Road	RTA	one lane blocked	0852-0857	85122	0852	85127	0857	85114	0900
16/11/99	A35	Millbrook Road	RTA	one lane blocked	0856-0940	75122	0856	75123	0901	75127	0940
17/11/99	A35	Redbridge Causeway	RTA	one lane blocked	1628-1730	84522	1625	84523	1630	84514	1721

Date	Road	Location	Cause	Severityyyynt	Duration	Code1 Location	Time1 Time	Code2 Location	Time2 Time	Code3	Time3
02/12/99	A35	Millbrook Road	RTA	one lane blocked	1733-1836	75523	1733	75522	1821	75514	1836
03/12/99	A3024	Burseledon Road	RTA	one lane blocked	1814-1824	20521	1814	20514	1824		
06/12/99	A33	The Avenue	RTA	one lane blocked	1145-1505	96122	1147	96114	1505		
07/12/99	A35	Totton By-pass	RTA	Road clsodure	1722-1850	85122/522	1722	85114	1738	84523	1810
09/12/99	A3024	Bittern Road East	RTA	one lane blocked	0930-0940	16122/522	0930				
09/12/99		tebouba/Ockley	RTA	one lane blocked	1338-1514	95122/522	1338	95114/514	1514		
11/12/99	A35	Redbridge Road	RTA	one lane blocked	1518-1620	84122	1518	84114	1620		
15/12/99	A3024	Northam Bridge	RTA	one lane blocked	1048-1113	79122	1052	79114	1113		
21/12/99	A35	Redbridge Road	RTA	one lane blocked	1725-1745	85522	1725	85523	1735	527	1745
21/12/99	A35	Redbridge Road	RTA	one lane blocked	1830-1840	85522	1830	527	1840	514	1845
21/12/99	A3024	Northam Bridge	RTA	one lane blocked	1456-	79122	1456	79142	1603		
23/12/99	A35	Millbrok road	RTA	one lane blocked	1727-1818	75523	1727	75122	1812	114	1818
29/12/99	A35	Redbridge Causeway	RTA	one lane blocked	0748-0852	84122	0748	84114	0852		
12/01/00	A35	Mountbatten Way	RTA	one lane blocked	0706-0721	76581	0706	514	0721		
17/01/00	A3024	Bursledon Road	RTA	one lane blocked	1750-1857	20122	1756	111	1857		
19/01/00	A335	Stoneham Way	RTA	one lane blocked	1326-1337	94522	1326	514	1337		
20/01/00	A35	Redbridge Road	RTA	one lane blocked	1335-	85581	1335				
23/01/00	A35	Redbridge Road	RTA	one lane blocked	1000-1459	85141	1000	114	1459		
26/01/00	A3024	Burseledon Road	RTA	one lane blocked	1746-1753	20123	1750	114	1753		
02/03/00	A33	The Avenue/Highfield	RTA	one lane blocked	1655-1734	96522	1655	96514	1734		
24/03/00	A3024	Bittern Road West	RTA	one lane blocked	1001-1018	17121	1001	114	1018		
24/03/00	A335	Thomas Lewis/St Denys	RTA	one lane blocked	1753-1755	97122/522	1753	127	1755	114	1806
27/03/00	A35	Redbridge Road	RTA	one lane blocked	1748-1835	84123	1748	84128	1758	84123	1805
09/04/00	A3024	Northam Bridge	RTA	one lane blocked	1125-1135	79181	1125	114	1135		
12/04/00	A35	Redbridge Road	RTA	one lane blocked	0827-0831	85123	0827	85127	0831	114	0838
12/04/00	A35	Redbridge Causeway	RTA	one lane blocked	1114-1121	84581	1114	114	1121		
17/04/00		Town Quay	RTA	one lane blocked	1515-1605	99142	1515	114	1605		
18/04/00	A35	Redbridge Road	RTA	one lane blocked	1310-	85122	1310				

Date	Road	Location	Cause	Severityyyynt	Duration	Code1 Location	Time1 Time	Code2 Location	Time2 Time	Code3	Time3
19/04/00	A3024	Northam Bridge	RTA	one lane blocked	1345-1413	79122/522	1345	514	1413		
25/04/00	A35	Redbridge Causeway	RTA	one lane blocked	1700-1728	84122	1700	121	1724	114	1728
27/04/00		Town Quay	RTA	one lane blocked	0845-1436	99142	0845	141	0938	114	1456
09/05/00	A33	The Avenue	RTA	one lane blocked	1440-1547	96122	1440	124/524	1542	114/514	1547
15/05/00	A35	Mountbatten Way	RTA	one lane blocked	1720-1806	76122	1720	114	1806		
19/05/00	A35	Millbrook Road	RTA	one lane blocked	0934-0939	75521	0934	114	0939		
20/05/00	A3024	Northam Bridge	RTA	one lane blocked	0953-1054	79122/522	0953	79123	1004	79514	1008
24/05/00	A35	Redbridge Causeway	RTA	one lane blocked	1400-1445	84122/522	1400	147	1435	114	1445
24/05/00	A3024	Bittern Road West	RTA	one lane blocked	1655-1705	17522	1655	17523	1705		
02/06/00	A33	The Avenue/Winn Road	RTA	one lane blocked	0825-0857	96122/521	0825	124/514	0848	114	0857
05/06/00	A35	Redbridge Road/Rush	RTA	one lane blocked	1750-1805	85523	1750	85523			
06/06/00	A33	The Avenue	RTA	one lane blocked	1607-1628	96122/96522	1607	121/114/514	1628		
07/06/00	A33	The Avenue/Burgess Rd	RTA	one lane blocked	0700-0715	96122/522	0700	114/514	0715		
09/06/00	A33	Basset Avenue	RTA	one lane blocked	1120-	14581	1120				
12/06/00	A335	Onslow Road	RTA	one lane blocked		15122/522	1025	123	1035	114/514	1050
16/06/00	A35	Rushiton Round About	RTA	one lane blocked	1718-1750	92527	1718	514	1750		
22/06/00	A35	Millbrook Doad	RTA	one lane blocked	1305-1335	75522	1305	514	1335		
30/06/00	A335	Thomas Lewis Way	RTA	one lane blocked	1525-1620	97522	1525	514	1620		
04/07/00	A35	Redbridge Causeway	RTA	one lane blocked	1446-1526	84122	1446	84123	1455	84122	1518
10/07/00	A35	Redbridge Causeway	RTA	one lane blocked	1635-1643	84522	1635	84527	1643		
10/07/00	A35	Redbridge Causeway	RTA	one lane blocked	1433-1453	84121	1433	84123	181	1448	114
15/07/00	A35	Redbridge Causeway	RTA	one lane blocked	1212-1252	84122	1212	84114	1252		
24/07/00		Marchwood By pass	RTA	one lane blocked	1625-1746	78122	1625	127	1746	114	1756
26/07/00	A35	Redbridge rbt	RTA	one lane blocked	1802-1839	84122	1802	123	1825	127	1839
01/08/00	A3024	Bittern Road West	RTA	one lane blocked	1103-1125	17122	1103	125	1125		
08/08/00	A335	Stonham Lane	RTA	one lane blocked	1604-1617			114	1617		
22/08/00		Tebourba/tesco	RTA	one lane blocked	1840-1850	95522/122	1840	514/114	1850		
25/08/00	A35	Redbridge Road	RTA	one lane blocked	1556-1617	85122	1556	114	1617		

Date	Road	Location	Cause	Severityyyynt	Duration	Code1 Location	Time1 Time	Code2 Location	Time2 Time	Code3	Time3
29/08/00	A35	Millbrook Road	RTA	one lane blocked	0900-1000	75121	0900	114	1000		
05/09/00	A35	Redbridge Causeway	RTA	one lane blocked	0937-1034	84122	0937	123	0954	114	11:00
13/09/00	A335	Thomas Lews Way	RTA	one lane blocked	0913-	97122	0913	121	0923		
18/09/00	A3024	Bittern Road West	RTA	one lane blocked	1437-	17512	1437		1535		
18/09/00	A35	Redbridge Causeway	RTA	one lane blocked	1522-1526	84122	1522	127	1526	114	1527
26/09/00	A3024	Burseledon Road	RTA	one lane blocked	1836-1848	20525/125	1836	127/527	1848		
27/09/00	A35	Millbrook Road	RTA	one lane blocked	1705-1740	75122	1705	121	1626	114	1740
03/10/00	A3024	Northam Bridge	RTA	one lane blocked	0720-0725	79122	0720	114	725		
03/10/00	A35	Redbridge Causeway	RTA	one lane blocked	1455-1606	84122	1455	123	1524	127	1606
04/10/00	A33	The Avenue/Westwood	RTA	one lane blocked	1720-1739	96122/522	1720	96127/527	1739	96114/514	1753
08/10/00		West Quay Road	RTA	one lane blocked	1217-1326	76211	1217	214	1326		
09/10/00	A33	The Avenue	RTA	one lane blocked	1200-1217	96121	1200	127	1217	114	1222
11/10/00	A33	Basste Avenue	RTA	one lane blocked	1723-1805	14122	1723	114	1805		
12/10/00	A35	Redbridge Road	RTA	one lane blocked	1605-1622	85522	1605	523	1612	527	1622
31/10/00	A35	Millbrook Road	RTA	one lane blocked	1206-1249	75122	1206	114	1249		
01/11/00	A35	Millbrook Road	RTA	one lane blocked	0758-0814	75123	0758	127	0814	114	924
03/11/00	A3024	Bursledon Road	RTA	one lane blocked	1820-	20121/521	1820				
08/11/00	A35	Redbridge Causeway	RTA	one lane blocked	1338-1402	84122	1338	114	1402		
09/11/00	A35	Redbridge Causeway	RTA	one lane blocked	1115-1120	85522	1115	114	1120		
10/11/00	A33	The Avenue/Burgess Road	RTA	one lane blocked	1000-1036	96122/522	1000	114/514	1036		
13/11/00	A35	Redbridge Road	RTA	one lane blocked	1739-1741	85582	1739	114	1741		
15/11/00	A33	The Avenue	RTA	one lane blocked	1803-1815	96121	1803	96114	1815		
20/11/00	A35	Redbridge Causeway	RTA	one lane blocked	0750-0804	84122	0750	84123	0800	127?	0804
20/11/00		West Qquay Road	RTA	one lane blocked	0950-1000	99121	0950	99114	1000		
24/11/00	A35	Redbridge Causeway	RTA	one lane blocked	1531-1628	84121	1531	84114	1628		
01/12/00	A35	Mountbatten Way	RTA	one lane blocked	1706-1809	76523	1706	76522	1743	76523	1751
05/12/00	A35	Redbridege Road	RTA	one lane blocked	1207-1212	85522	1207		1212		
06/12/00	A35	Redbridge Flyover	RTA	one lane blocked	1820-1831	85523	1820	85514	1831		

Date	Road	Location	Cause	Severityyyynt	Duration	Code1 Location	Time1 Time	Code2 Location	Time2 Time	Code3	Time3
06/12/00	A33	Bassett Ave	RTA	one lane blocked	1400-1448	14122/522	1400	14123/523	1411	127/527	1448
07/12/00	A35	Redbridge Road	RTA	one lane blocked	0818-0825	85122	0818	85127	0825		