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Paper title: **A stated preference survey for investigating route choice behaviour in Adelaide**

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Abstract (200 words):
Systems which provide traffic information are installed in many areas to support driver route choice. Variable Message Signs (VMS) are one of the tools for providing traveller information and have much potential in portraying traffic conditions in a timely manner. This paper describes a research project that studies drivers' route choice behaviour in response to the content of VMS. In particular, the influencing factors for drivers are investigated including: types of incidents, degree of congestion, status of congestion and location of an incident. Verification of drivers' perception about some qualitative delay time information is also examined. A Stated Preference survey by questionnaire was conducted with residents along a target route in Adelaide. Binary logit models were developed for drivers' route choice preference and other significant factors such as: socio-economic factors, familiarity with the road network and experience of VMS. The results indicate that the content of VMS influences route choice behaviour. In particular, the degree of delay, status of congestion and location of incident are significant factors influencing the probability of diversion. Results also indicate that differing characteristics and the experience of each driver influences route choice behaviour.

Introduction

Advanced Traveller Information Systems (ATIS) are one of the important components of Intelligent Transportation Systems (ITS). These systems provide drivers with information and are thought to be ideal tools for using limited road capacity more efficiently via traffic diversion. A lot of information providing systems have already been installed in many jurisdictions and many countries. There are several methods to provide drivers with information including: radio broadcasting, telephones, web sites, graphic panels at information kiosks, on-board navigation systems and variable message signs. These provide real-time traffic information on things such as traffic congestion, delay time, incidents and travel time so as to support drivers' route choice decision.

Variable Message Signs (VMS) can be used for various aims but the main purpose of VMS is to inform drivers of road conditions ahead. The messages provided by a VMS are considered to have significant potential to influence drivers' decision-making processes. Message content can therefore be used as a traffic control variable to enhance traffic conditions. Many researchers (e.g. Bonsall et al 1997, Hato et al 1999) have conducted surveys and conclude that VMS is considered to be a very effective tool to influence the route choice of drivers.

Many previous studies reported on the effectiveness of VMS information on route choice decisions, however, the relationship between route choice behaviour and information content is still not clear. For example, an early study found that the information from a VMS could persuade in the range of 5 to 80 % of drivers to divert, but this range is too wide for prediction and modelling purposes (Bonsall et al 1995, Wardman et al 1997, Hidas et al 2001).

In addition, the mechanism of drivers' route choice behaviour is very complex and route choice is considered to be decided by a combination of several factors. VMS message content has been established as a very important factor (Bonsall et al 1995) but other factors including the road network, such as hierarchy of roads, toll roads, degree of congestion, and special event will influence route choice as well. In particular, differing driving characteristics and the experience of each driver will have differing criterion for route choice decision-making. Therefore, it is very important to collect various kinds of data to know the mechanism of drivers' route choice behaviour, though it is very difficult to achieve general models that can be used in any location.

The primary objective of this research is to develop a model capable of substantiating travellers' route choice behaviour in response to Variable Message Signs (VMS) on a target route in the Adelaide CBD. The route choice model is focused on the relationship between the content of VMS and the degree of diversion resulting from information provided to motorists.

In order to develop a route choice model, it is necessary to investigate the fundamental factors that influence route choice behaviour. The major factors considered in this study are the effect of message content on drivers' route choice. Decision-making processes for route choice may be influenced by the differing characteristics and experience of drivers. Some of these factors may include socio-economic factors, familiarity with the road network, previous experience of VMS and familiarity with VMS.

This paper discusses the survey approach used and results of data analysis including: drivers' general characteristics, drivers' desire for VMS information and perception of some qualitative delay time messages. Some preliminary route choice models are presented and characteristics of the models discussed.

Survey approach

The Revealed Preference (RP) and Stated Preference (SP) approach are two basic methods to examine drivers' route choice behaviour. The RP approach is used to examine existing roads or conditions and to investigate how drivers make their choice in real situations. Network monitoring and interviews are two survey methods of the RP. The advantage of the RP approach is the validity of collected data, whilst the disadvantages of the RP approach are high cost and difficulty of data collection on hypothetical scenarios.

The SP approach is used to investigate how drivers behave in hypothetical situations. The advantages of the SP approach are that data can be collected in a controlled situation and is relatively cheaper than the RP approach. The disadvantages are that the SP data can be biased as it is collected in hypothetical situations. Typical techniques of the SP approach use travel simulators and questionnaires. With travel simulators, researchers are able to control data sets, parameters and situations easily, but it is very difficult to represent the real world situation and also need much time to develop (Bonsall et al 1997). On the other hand, questionnaire surveys are capable of representing the real world situation in relation to the drivers' actual trip. For this reason, many researchers have used the questionnaire survey approach and reported many useful results for fundamental characteristics of route choice behaviour (Chatterjee et al 2002, Hidas et al 2001, Wardman et al 1997, Peeta et al 2000). Therefore, an SP survey by questionnaire was selected in this research.

Survey design

- The Adelaide Central Business District (CBD) in South Australia is the central area of the Adelaide city (Figure 1).

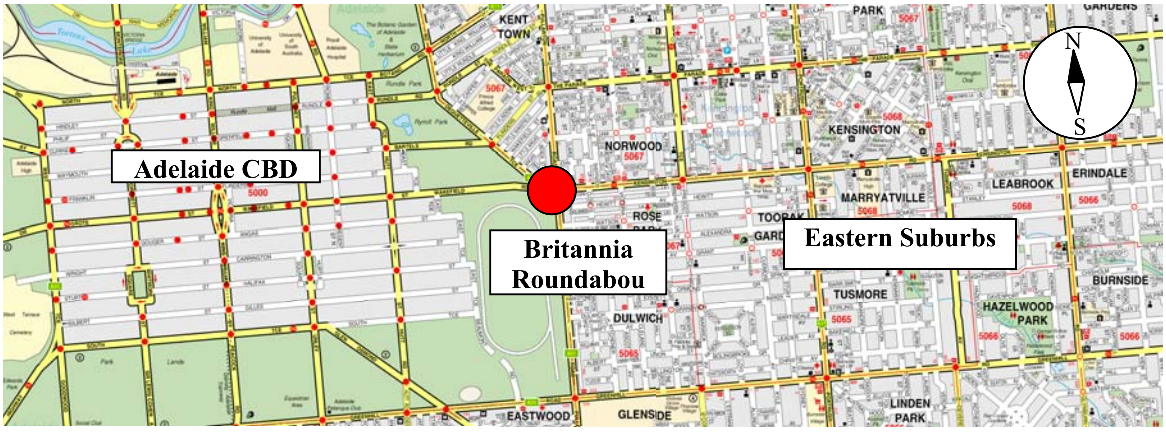


Figure 1 Location of the Adelaide CBD and the Britannia Roundabout

The CBD is suitable for studying drivers' route choice in response to the VMS messages for the following reasons:

- As there is much traffic volume into and out of the CBD, the traffic congestion, especially in peak-hours in the morning and evening often becomes a major problem.

- The road network in the CBD consists of a grid network; hence many options exist to examine traffic route choice.

VMS has not been implemented in the CBD, whereas the potential need for traffic information is high.

The characteristics of drivers in Adelaide compared with other major cities in Australia or other countries are that drivers have less experience of VMS messages because VMS are not used extensively for traffic management in Adelaide by the road authorities.

Britannia Roundabout

The Britannia roundabout is located to east of the Adelaide CBD. Adelaide drivers have widely regarded it as one of the most troublesome and risky intersections to traverse in the city. Five major arterial roads cross at this intersection (Figure 2). Due to the structure of this intersection, traffic movements are very slow, particularly during peak hours. This study focuses on the west-east movement between Wakefield Road and Kensington Road at the Britannia Roundabout for the following reasons:

- Recurring traffic congestion, especially in peak-hours in the morning and evening often causes long queues and delays at this intersection due to over saturation.
- Although many modifications and suggestions have been undertaken to improve the intersection, congestion and accidents have not yet been effectively prevented. In addition, the possibilities of restructuring this intersection are limited.
- Wakefield Road and Kensington Road connect the inner city and eastern suburbs and carry considerable traffic into and out of the CBD.
- The longest queues during peak hour occur on Wakefield Road eastbound.

According to a previous research report by Transport SA (1996), improvements in the structure of the Britannia roundabout have been under consideration for some time. Although its operation has been improved some modifications, the general trend of high accidents and over saturation in peak hours remain unresolved. A traffic movement survey of existing traffic flow was conducted and the data revealed drivers' willingness for route choice when drivers encounter long queues and delays. Some drivers decided to avoid the Britannia Roundabout and use alternatives including back streets. The study concluded that drivers could not know how long it would take to go through the intersection. The report cited that "traffic leaving the city avoids Wakefield Road and uses other arterial routes" in order to avoid encountering long queues and delays. The queue length on Wakefield Road was approximately 400m to 500m, and average delay per vehicle was approximately 30 seconds during the evening peak hour. This report concluded that traffic control facilities, such as traffic signals, would reduce road crashes, but it also suggested that greater approach capacity would be required.

Figure 2 Structure of the Britannia Roundabout

Clearly, the need for a resolution to the problems at this intersection remains high. The implementation of ITS tools, particularly, VMS must be able to assist both drivers and transport authorities. If VMS displays real time information to drivers before approaching the intersection, they will have the option of choosing an alternate route for their trip.

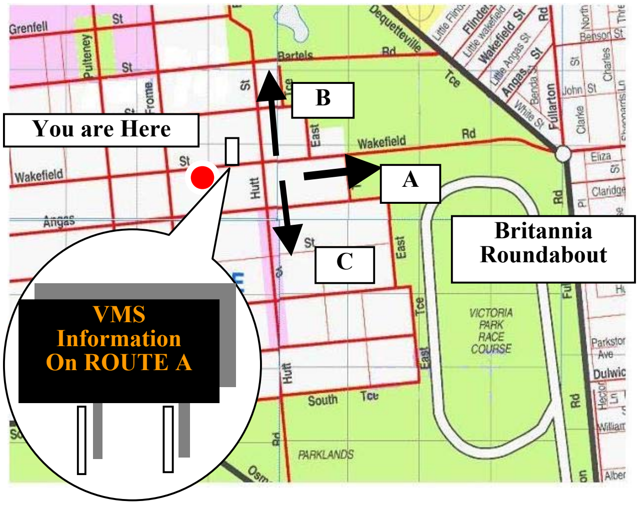
An SP survey by questionnaire

The 15 page questionnaire contained the following items in order to collect route choice preference at the target roads and drivers' characteristics.

- ***VMS content:*** this section enquires about route choice in response to hypothetical VMS messages that display the following content:
  - *Cause of delay (Accident, Roadworks, Congestion)*
  - *Delay time (10 min delay, 15 min delay, Expect delay etc.)*
  - *Queue length (100m long, 200m long etc.)*
  - *Status of congestion (Congestion Increasing / Decreasing)*
  - *Location of incident*

Some VMS messages combine two or more messages listed above. A sample question is shown in Figure 3.

Suppose that you are driving on Wakefield Street in the Adelaide CBD, and you are travelling towards your home (or destination) via Kensington Road. If the VMS displays the following message on **ROUTE A**, which route will you choose?



Accident At Britannia Roundabout 15min Delay

☐A ☐B ☐C (Tick one)

Accident Ahead Congestion Decreasing

☐A ☐B ☐C (Tick one)

Figure 3 Examples of the questions used in the questionnaire

- ***Familiarity with the target road***: to investigate driving experience and familiarity with the target road including the road network.
- ***Experience with VMS***: to investigate previous experience with VMS and enquire about drivers' opinion of VMS messages including need of VMS.
- ***Verification of qualitative messages***: to investigate drivers' perception of qualitative delay time messages (e.g. "Expect Delay", "Minor Delay")
- ***Socio-economic factors***: personal characteristics of drivers including age, gender, occupation, level of education and income.

Questionnaire distribution

A questionnaire distribution area was selected taking account of residential areas where the target road users were most likely to live. This area measured approximately 2 x 4 kilometres in the eastern suburbs of Adelaide. Wakefield Street via Britannia Roundabout is the shortest path to the central area in the CBD for almost all residents in the target area. Therefore, route choice behaviour and propensity of drivers living in this area was considered to reflect the characteristics of road users on the target road.

Existing data (census 2001) was used to estimate the number of households. The total number of households in this area was 8949. A total of 1000 questionnaires were distributed to mailboxes over two days in March 2004. The questionnaires were distributed to every ninth household in the target area. The questionnaire was enclosed with a covering letter and an A4 self-addressed reply-paid envelope. A due date was set for 10 days after the distribution dates and approximately 70% of the replies were received by the due date and 90% a week after the due date.

Results

A total of 266 of the 1000 questionnaires were returned (26.6%) but 21 questionnaires were incomplete. Therefore, a total of 245 questionnaires were used for data analysis (24.5%). The return rate was higher than expected despite the number of pages (15 pages) and complexity of the questionnaire. This is attributed to the interest for the target route (Wakefield Street, especially the Britannia Roundabout) and timing of the survey because a motor racing event took place using public roads including Wakefield Street and the Britannia Roundabout just a week before the survey.

Data analysis

General characteristics

Table 1 shows the socio-economic characteristics of the respondents. The gender of the respondents was fairly even with 52% male and 48% female. The distribution in terms of age groups was approximately even except for the less than 30 age group.

The primary occupations of the samples were executive/professional, retired and administrative. The average annual income of the household was A$82,000 and more than 66 % of respondents had at least university level education.

Table 1 Socio-economic Characteristics

Attribute	% of sample	Attribute	% of sample
Gender		Occupation	
Male	52.2	Executive/ Professional	42.0
Female	47.8	Administrative	11.4
Age		Education	6.5
Under 20	2.4	Sales	2.4
21-30	8.6	Trade person	1.2
31-40	17.6	Labourer	0.4
41-50	24.4	Retired	22.4
51-60	23.3	Unemployed	0.4
Over 60	23.7	Home duties	5.3
Income (Household / Year)		Professional driver	0.4
Under 20,000	5.3	Full time student	5.3
20,000-40,000	13.5	Other	2.0
40,000-60,000	18.7	Education level	
60,000-80,000	14.3	Secondary	17.4
80,000-100,000	12.7	College	16.1
1 00,000-150,000	14.7	Undergraduate	36.0
Above 150,000	15.5	Postgraduate	30.5
No answer	13.0	Other	3.8

Although the response rate of older age groups seemed to be higher, the distribution of age corresponds to census demographic data of the distribution area. The high percentage of particular jobs and education level has been experienced in other studies in Brisbane (Dia 2002) and Hong Kong (Lai et al 2000). The study conducted in Brisbane shows a very similar tendency of education level and occupation rate except the high percentage of retired people.

The reason why the retired became a high percentage may be related to the age category and survey method. Previous researchers distributed questionnaires on site whereas, in this survey, questionnaires were distributed to the mailbox of households. Older people (especially retired) will have enough time to answer the questionnaire; therefore, there is a high probability that older people reply to the questionnaire instead of younger people in the family.

Trip characteristics

Table 2 shows the trip characteristics of the respondents. Approximately 55 % of the respondents drove in the Adelaide CBD during peak hour (morning and evening) and 96 % drove alone or with one passenger. The main purpose of driving was commuting and shopping. More than 80 % of the respondents had their trip destination in the CBD, whilst almost 20 % of the respondents drove through the CBD to pass to their destination. In regard to familiarity with the road network in the CBD, more than 85 % of the respondents answered that they were familiar with roads in the CBD. In other words, it can be said that many respondents are familiar with alternatives as well. 84 % of the respondents used the Britannia Roundabout but approximately 30 % chose alternatives depending on traffic conditions. In regard to the previous experience of VMS, most respondents answered they had seen VMS messages before but the frequency was low. 15 % of the respondents answered that they saw VMS more than 20 times during last 12 months but others saw VMS messages at most twice during one month.

Table 2 Trip Characteristics

Attribute	%	Attribute	%
Time of day driving in the CBD		Familiarity with the CBD	
Peak hour	54.8	1 : Not familiar	0.4
Off peak hour	45.2	2 :	1.6
Passenger		3 :	11.8
alone	68.2	4 :	37.1
1 passenger	27.8	5 : very familiar	49.0
2 passengers	3.7	Use Britannia Roundabout	
3 passengers	0.4	Yes	52.2
Purpose		Yes, but sometimes use alternatives	31.8
Commuting	46.7	No	15.9
Shopping	27.0	Have you seen VMS?	
Other	26.3	Yes	89.8
Trip destination		No	10.2
CBD	81.4	Frequency of VMS	
Other	18.6	Many	15.1
		Not many	85.0

Drivers' desire for VMS messages

Table 3 shows the results of respondent opinions about the desire for VMS messages that will influence route choice decision if the messages are available for display on a VMS. The score of each message is described as the average of a 5-point scale. The results indicate that the respondents want to obtain quantitative information more than qualitative information. In particular, *Delay time information* is the highest requirement for route choice decision-making. Of the qualitative information, *location of incident* and c*ause of incident* will have an impact on the route choice, whereas many of the respondents think that *status of congestion* will influence their route choice behaviour less than other factors.

Verification of qualitative delay time messages

Some qualitative information has been used like quantitative information. Such VMS messages are very convenient for transport authorities to display in a practical matter because the messages just indicate abstract ideas and do not need to display the exact information. With this, drivers cannot know the exact information and, therefore have to imagine or interpret the information.

A gap between drivers' perception and that of the transport authorities was identified as an important issue. For example, *Minor Delay* and *Major Delay* are used below 15 minutes delay and over 15 minutes delay in urban areas respectively by the Transport Authority in South Australia. *Expect Delay* is used if no information is available on the extent of delays (VMS operational instruction manual).

Table 3 Drivers opinions about desire for VMS messages

Message on VMS	Delay time	Queue length	Location	Cause	Status
Mean of 5 point scale	3.6	3.2	3.0	2.9	2.6

Therefore, an analysis of some delay time messages is performed in order to understand drivers' prediction time to verify the perception. The following VMS messages were examined in this survey: a) Expect Delay, b) Minor Delay, c) Long Delay, and d) Major Delay.

Table 4 and Table 5 show the number of responses for each VMS message. Approximately 43 % of respondents perceived the message "*Expect Delay"* as 10 minutes delay and 89% of the respondents think it less than 15 minutes delay. In regard to the message of *Minor Delay*, approximately two thirds of the respondents perceived this as 5 minutes delay and almost 95 % of the respondents perceived it as less than 10 minutes delay. In addition, 100 % of the respondents thought *Minor Delay* related to less than 15 minutes delay.

In terms of *Long Delay*, the mode was 30 minutes delay with approximately 32 %. A total of 77 % of the respondents perceived "*Long Delay"* to mean less than 30 minutes delay, whereas almost 10 % of the respondents perceived it as 60 minutes or more delay. By contrast, in the case of *Major Delay,* the mode was the same as "*Long Delay"* (30 minutes delay with 28 %), but only half of the respondents perceived it as less than 30 minutes delay. On the other hand, approximately 32 % of the respondents thought the message "*Major Delay"* as 60 minutes or more delay.

Descriptive analysis was performed and the results are summarized in Table 6. A graph in the case of *Expect Delay* is shown in Figure 4.

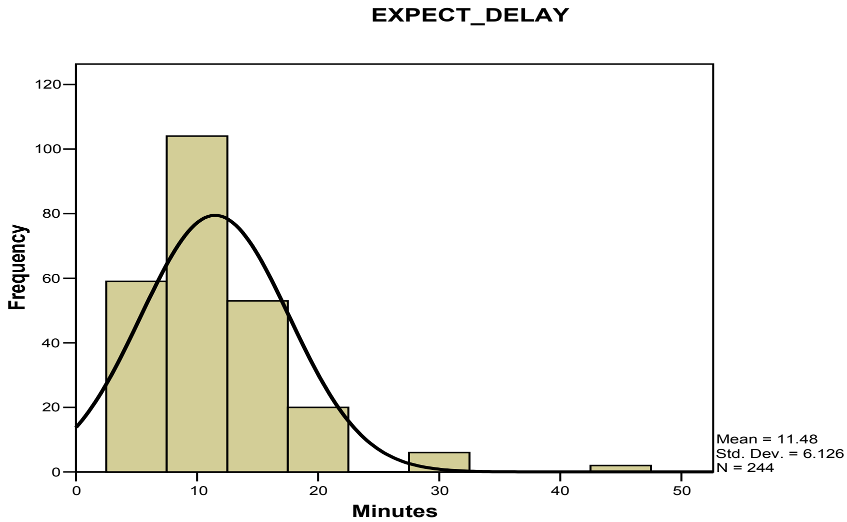


Figure 4: Distribution of expected delay time using the message "Expect Delay"

Table 4 Rate of delay time anticipation: *Expect Delay, Minor Delay*

	5 min	10 min	15 min	20 min	30 min	Over 30
Expect Delay (%)	24.2	42.6	21.7	8.2	2.5	0.8
Minor Delay (%)	65.6	29.1	5.3	0	0	0

Table 5 Rate of delay time anticipation: *Long Delay, Major Delay*

	10 min	15 min	20 min	30 min	45 min	60 min	Over 60
Long Delay (%)	5.3	17.6	22.5	31.6	13.5	5.7	3.7
Major Delay (%)	2.9	6.6	15.6	28.0	15.2	18.5	13.2

Table 6 Statistical result of delay time messages

VMS message	Expect Delay	Minor Delay	Long Delay	Major Delay
Number of sample	244	244	244	243
Mean	11.48	6.99	30	42.61
Mode	10	5	30	30
Std. Deviation	6.13	2.95	17.31	23.67
Variance	37.53	8.69	299.59	560.19
Skewness	2.02	1.19	1.7	0.78

Note that the answer of "Over 30 minutes" in the question of *Expect Delay* and *Minor Delay*, and "Over 60 minutes" in the question of *Long Delay* and *Major Delay* was translated into 45 minutes and 90 minutes respectively in order to examine a distribution.

The mean of the expected delay time for each VMS message (*Expect Delay*, *Minor Delay*, *Long Delay* and *Major Delay*) was approximately 12, 7, 30 and 43 minutes respectively.

Compared between similar types of VMS messages (such as *Expect Delay* and *Minor Delay*, *Long Delay* and *Major Delay*), the perceived delay time for the respondents about *Minor Delay* was less than that of *Expect Delay*. On the other hand, *Major Delay* was perceived almost 1.5 times longer than *Long Delay*. The variance of *Expect Delay* and *Minor Delay* was smaller but *Long delay* and *Major Delay* was larger.

Summarizing the results, the following were found:

- The respondents think *Minor Delay* is the shortest time of delay followed by *Expect Delay*, *Long Delay* and *Major Delay* with approximately 7 minutes, 12 minutes, 30 minutes and 43 minutes respectively.
- The VMS message of *Expect Delay* and *Minor Delay* was perceived with less variance time amongst the respondents, whereas, the message of *Long Delay* and *Major Delay* had large variance. The message "*Major Delay*" may have significant gaps of delay time perception amongst drivers.
- No gap in relation to the delay time information between drivers' perception and transport authorities was found. Transport authorities expect the VMS messages, *Minor Delay*, as less than 15 minutes delay whilst 100 % of the respondents perceived it as less than 15 minutes delay; likewise, *Major Delay* is used more than 15 minutes delay whilst approximately 97 % of the respondents perceived as more than 15 minutes delay.

Modelling

A discrete choice model was employed to develop route choice models in order to examine drivers' route choice behaviour in response to the content of VMS. The discrete choice model is based on an assumption to maximize the utility of individuals; random utility theory can allow the presentation of unobservable attributes from the survey. There are several types of discrete choice model forms (Ben-Akiva et al 2002) and when the Gumbel distribution is used for the random part, it is called a Logit model. In this research, a binary logit model was employed for the analysis of collected data as this study was only interested with localised traffic diversions along a target route and a desire to keep things simple. Available resources only permitted data collection in a localised area in relation to the target route. The route was carefully chosen to represent two real alternatives out of the city, namely using the Britannia Roundabout or not using the roundabout.
From the concept of random utility theory, the forms of utility function U representing alternatives i (Route A) and j (others) of individual n are:

$$U_{in} = V_{in} + \varepsilon_{in}$$

$$U_{jn} = V_{jn} + \varepsilon_{jn}$$

Where $V_{i(j)n}$ is the deterministic part and $\varepsilon_{i(j)n}$ is the random part.

The probabilities of choosing i and j of individual n are given by:

$$P_{in} = \frac{1}{1 + e^{-(V_{in} - V_{jn})}}$$

$$P_{jn} = 1 - P_{in}.$$

The difference of the utility between the alternatives i and j of individual n can be represented as the following form:

$$V = V_{in} - V_{jn} = ASC + \Sigma\, \beta_k X_{ink} + \Sigma\, \alpha_m Y_{inm}$$

Where ASC is alternative specific constant, B_k is coefficient (estimated parameter) of attribute k for alternative i, X_{ink} is explanatory variable of attribute k for alternative i except VMS message, α_m is coefficient (estimated parameter) of VMS type *m* for alternative *i,* and Y_{inm} is dummy explanatory variable of VMS type *m* for alternative *i.*

Explanatory variables in the developed models and coding system are shown in Table 7. The binary dummy codes used in the models (age and income) were approximately the average value of the respondents and were considered sufficient for developing the models. The models controlled for destination as well as trip purpose because the survey distribution area was assumed to align with the destination of the respondents.

Results

For the first step, a general model was constructed using the data collected by the questionnaire. The results of parameter estimation are shown in Table 8.

Table 7 Explanatory variables in models

Explanatory Variables	Codes
Purpose of trip	1 if commuting, 0 otherwise
Passengers	1 if driving with passengers, 0 otherwise
Familiarity with the CBD	1 if familiarity is "4" or "5" in Table 2, 0 otherwise
Experience of VMS	1 if drivers have seen VMS before, 0 otherwise
Frequency of VMS	1 if saw VMS more than 21 times last 12 months, 0 otherwise
Gender	1 if male, 0 if female
Age	1 if less than 40 years, 0 otherwise
Education	1 if "Graduate" and "Postgraduate", 0 otherwise
Income	1 if more than A$80,000, 0 otherwise
Area	1 if live nearer area from Route A than alternatives, 0 otherwise
VMS (Dummy variables for each VMS messages)	1 if choose route A, 0 otherwise

Model 1 applies to the full parameter sets that include all explanatory variables in the estimation process. Model 2 applies selected parameter sets of statistically significant variables (at the 5 % level).

The Alternative Specific Constant (ASC) shown as the constant in Table 8 represents the average effect on utility of unobserved factors in the model. ASC plays a similar role of a constant in a regression model. If ASC is included in a model, the remaining unobserved error becomes zero mean. Therefore, if the ASC for an alternative becomes statistically significant, then the model is recognized as capturing unobserved factors with a high probability (Train 2003). In the general model, ASC also means the utility of willingness to choose the target road in the case that no VMS message is provided to the respondents and the relevant explanatory variables take a zero value. The positive sign of a constant implies that respondents are likely to choose Route A.

Table 8 General Model

	Model 1		Model 2	
	Coefficient	t-statics	Coefficient	t-statics
Constant	1.919	6.464	2.062	7.119
Purpose of trip	0.297	2.276	0.333	2.711
Passengers	0.141	1.105**		
Familiarity with the CBD	-0.748	-4.542	-0.723	-4.481
Experience of VMS	-0.671	-3.934	-0.653	-3.932
Frequency of VMS	-0.287	-1.468**		
Gender	0.137	1.143**		
Age	0.662	5.176	0.677	5.544
Education	0.231	1.745**		
Income	0.246	2.015*	0.273	2.271*
Area	0.666	5.486	0.673	5.617
VMS				
V1: Congestion Ahead	-3.050	-12.400	-3.029	-12.371
V2: Accident Ahead	-3.864	-13.878	-3.840	-13.847
V3: Roadwork Ahead	-2.687	-11.311	-2.668	-11.282
V4: Congestion Ahead Use Alternative	-5.549	-12.138	-5.523	-12.100
V5: Congestion Expect Delay	-3.782	-13.797	-3.758	-13.767
V6: Congestion 10 min Delay	-3.362	-13.139	-3.340	-13.110
V7: 10 min Delay Congestion Increasing	-4.437	-13.970	-4.411	-13.935
V8: 10 min Delay Congestion Decreasing	-2.448	-10.484	-2.431	-10.455
V9: Congestion at BR 10 min Delay	-3.864	-13.878	-3.840	-13.847
V10: Congestion at BR 10 min Delay Use Alternative	-3.998	-13.972	-3.974	-13.940
Number of observations	2552		2552	
L(0)	-1354.2		-1354.2	
L(β)	-994.7		-999.1	
Adjusted R square	0.2593		0.2573	
BR: Britannia Roundabout	* Insignificant at 1 %.		** Insignificant at 5 %.	

Model 1 indicates that age and income significantly influence route choice. The effect of age has a positive sign indicating younger drivers are likely to use Route A, whilst elder drivers have a propensity to avoid taking Route A. Income also has a positive sign implying high income drivers are more likely to choose Route A. The coefficient value of age is higher than income suggesting that age is more likely to influence route choice behaviour than income. Other factors including gender and education are not statistically significant implying there is no significant difference between males and females and amongst education levels to influence route choice.

In regard to trip characteristics, the following factors influence route choice: purpose of trip, familiarity with the CBD, previous experience of VMS and living area. A positive sign for purpose of trip indicates commuters are likely to use Route A. Also living area is positive indicating that drivers living in nearer area from Route A than alternatives have a propensity to take Route A. The results mean that commuters and dwellers in the area are likely to avoid wasteful longer trips and willing to use the shortest path. The result of a negative sign in terms of familiarity with the CBD indicates that drivers who know road network and alternatives in the CBD well are likely to choose alternatives. Experience of VMS is also negative implying that drivers who saw VMS messages before react more sensitively than inexperienced drivers. Other factors such as the number of passengers and the frequency of seeing VMS messages are not statistically significant at the 5 % level.

Focusing on the effect of VMS messages, all messages are statistically significant at the 1 % level. The results imply that all content of VMS messages influence route choice. In addition, all coefficients show a negative sign indicating that the probability of diversion will increase if any of VMS messages are provided to drivers.

Comparing VMS messages, the following were found:
Cause of incident: In comparison with VMS messages (V1-V3), “Accident Ahead” has the highest coefficient value indicating that the probability of diversion is significantly increased if the VMS displays “Accident Ahead”. If the VMS displays “Congestion Ahead” and “Roadwork Ahead”, the probability of diversion is increased as well but will be smaller than Accident. Interestingly, “Roadwork” has lower effectiveness than “Congestion”. The result implies that even if “Roadwork Ahead” is displayed on the VMS, some drivers may not associate this with traffic congestion and delay of trip directly, or may think the delays are still light. On the other hand, if the VMS displays “Congestion”, then drivers will perceive the VMS message as it is. Therefore drivers are likely to choose alternatives to avoid staying in a queue; as a result the probability of “Congestion” becomes higher than “Roadwork”.

Status of congestion: Information on *Increasing* and *Decreasing Congestion* influence route choice. The results of coefficient value V7 and V8 in Table 8 indicate that the probability of diversion is increased if the VMS displays “Congestion Decreasing”, “Congestion Ahead”, or “Congestion Increasing” (shown here in the case of 10 minutes delay only).

Location of incident: The model suggests that the probability of diversion is increased if the VMS displays the location of the incident. Compared with the coefficient value of “Congestion 10 min Delay” (V6) with “Congestion at Britannia Roundabout 10 min Delay” (V9), the absolute value of the VMS message including a location name is higher, implying that drivers are more likely to take alternatives in order to avoid using the Britannia Roundabout.

Route Recommendation: Information on Route Recommendation influences route choice significantly. The coefficient value of “Congestion Ahead Use Alternative” (V4) is much higher than that of “Congestion Ahead” (V1) indicating that the probability of diversion is increased if the VMS message recommends alternatives. The reason for the high probability may well be that drivers think of such information as compulsory or occurring as a serious incident forward of the route. The coefficient value of “Congestion at Britannia Roundabout 10 min Delay Use Alternatives” (V10) is higher than “Congestion Ahead” (V1) but much lower than “Congestion Ahead Use Alternatives” (V4). The value is relatively near to the message of “Congestion at Britannia Roundabout 10 min Delay” (V9). The results indicate that if there is more relevant information for route condition, drivers are able to make their route choice by themselves with more flexibly even if the VMS recommends other routes.

Delay time information: Model 1 implies that the probability of diversion is increased if the VMS displays the delay time information “Expect Delay” (V5) or “10 min Delay” (V6). The coefficient value of “Expect delay” is slightly higher than that of “10 min Delay” indicating that the probability of taking alternatives is higher, which corresponds to the result of verification in relation to qualitative delay time information mentioned previously.

Table 9 presents models describing quantitative VMS messages in order to compare the probability of diversion in terms of delay time information and queue length information.

Model 3 applies to the full parameter set and Model 4 applies to the reduced parameter set. The selected explanatory variables are statistically significant at the 5 % level.

The model clearly indicates that the probability of diversion is increased if the delay time is increased. The coefficient value of "5 min Delay" is much smaller than other parameters amongst delay time messages (V2-V7) implying the probability of diversion is very low.

Table 9 Quantitative Model

	Model 3		Model 4	
	Coefficient	t-statics	Coefficient	t-statics
Constant	1.341	4.594	1.548	6.262
Purpose of trip	0.161	1.317**		
Passengers	0.216	1.810**		
Familiarity with the CBD	-0.029	-0.173**		
Experience of VMS	-0.584	-3.486	-0.540	-3.287
Frequency of VMS	-0.404	-2.296*	-0.409	-2.345*
Gender	0.193	1.705**		
Age	0.512	4.154	0.490	4.167
Education	0.111	0.896**		
Income	0.511	4.436	0.599	5.452
Area	0.380	3.407	0.381	3.460
VMS (Condition of V2-V10: Congestion at BR)				
V1: Congestion Ahead	-2.967	-12.261	-2.948	-12.229
V2: 5 min Delay	-2.016	-8.906	-2.002	-8.879
V3: 10 min Delay	-3.762	-13.725	-3.741	-13.691
V4: 15 min Delay	-5.429	-11.959	-5.405	-11.922
V5: 20 min Delay	-6.550	-8.918	-6.525	-8.889
V6: Expect Delay	-4.146	-13.866	-4.124	-13.830
V7: Long Delay	-6.139	-10.055	-6.114	-10.022
V8: Queue 50 m Long	-1.684	-7.483	-1.672	-7.458
V9: Queue 100 m Long	-2.245	-9.829	-2.229	-9.800
V10: Queue 150 m Long	-3.183	-12.803	-3.163	-12.771
V11: Queue 200 m Long	-3.894	-13.816	-3.872	-13.781
V12: Queue 400 m Long	-5.130	-12.653	-5.107	-12.615
Number of observations	3016		3016	
L(0)	-1613.4		-1613.4	
L(β)	-1095.7		-1100.4	
Adjusted R square	0.3157		0.3139	

BR: Britannia Roundabout * Insignificant at 1 %. ** Insignificant at 5 %.

In other words, the probability of taking Route A is higher if the VMS displays this message. The coefficient value of "15 min Delay", "20 min Delay" and "Long Delay" is very large indicating that the possibility of taking alternatives is very high.

In regard to *queue length of congestion*, a similar trend is captured with the delay time information. The longer the queue a VMS displays, the more the probability of diversion is increased. The coefficient value of "Queue 50 m Long" is the smallest amongst VMS messages (V1-V12) indicating that the possibility of taking Route A is much higher if the VMS displays the message. On the contrary, the value of "Queue 400 m Long" is the largest amongst *queue length information* but is smaller than that of "15 minute delay". The result implies the probability of taking alternatives is still smaller than that of "15 minute delay".

Conclusion

This paper has presented the results of the impact of VMS messages on route choice behaviour in Adelaide. The study also concerned the differing characteristics and experience of each driver including socio-economic factors and trip characteristics in the Adelaide CBD. An SP survey by questionnaire was conducted in a residential area that the target road users were most likely to live in and discrete choice analysis was attempted to develop route choice models by using the collected data.

Based on the results, the following findings are summarized. Qualitative information (cause of incident, status of congestion, location of incident, route recommendation) and quantitative information (delay time information and queue length of congestion) influence route choice behaviour. In particular, status of congestion and route recommendation have much potential to influence route choice behaviour. In regard to cause of delay, if a VMS displays "A*ccident Ahead"*, the probability of diversion is higher than *Congestion* or R*oadwork*. The degree of delay time and queue length influences the probability of diversion sensitively. When delay time and queue length is shorter, the probability of diversion is low as respondents still preferred to stay in a queue and not take the alternative route.

This research found that *Location of incident* had a high significance. Age, income and previous experience of VMS are significant both of the general model and quantitative model. On the other hand, gender, education and passengers do not influence the probability of diversion in both models. Other factors including *purpose of trip*, *familiarity with road network* and *frequency of VMS* are significant in either general model or quantitative model.

This research analysed drivers' perception of delay time regarding to some qualitative delay time messages. The results show that "Expect Delay" and "Long Delay" is perceived as approximately 12 minutes and 30 minutes respectively. The results correspond to the values of the developed models.

As mentioned above, many findings are drawn from this survey though, there remains an issue of effective combination of VMS content. The probability of diversion may be influenced by the combination of VMS content. In general, the statement that "the more the amount of information, the higher the probability of diversion" is thought to be true, but too much information may cause confusion to drivers and may also be beyond the limitation of readable length. Further research is needed and results from this research indicate that the most important factor for the decision-making process may be not the amount of information but the relevant information on what drivers want to know.

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