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DRIVER'S RESPONSE TOWARDS TRAFFIC INFORMATION UNDER TRAVEL TIME VARIABILITY

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A Thesis Submitted in Partial Fulfillment of the Requirements
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รานี นุชาริชา: การตอบสนองของผู้ขับขี่ต่อข้อมูลการจราจรที่มีความแปรปรวนของเวลาการเดินทาง (DRIVER'S RESPONSE TOWARDS TRAFFIC INFORMATION UNDER TRAVEL TIME VARIABILITY), อ.ที่ปรึกษา: รศ .ดร.สรวิศ นฤปิติ, 137 หน้า

ระบบ Advanced Traveler Information System (ATIS) ได้ถูกนำมาประยุกต์ใช้ในหลายประเทศ เพราะว่าระบบ ATIS เป็นวิธีการที่มีศักยภาพที่จะแก้ปัญหาการจราจรคับคั่งและเพิ่มคุณภาพการขับขี่ เมื่อระบบให้ข้อมูลด้านการจราจรแก่ผู้ขับขี่จะส่งผลให้ผู้ขับขี่ตัดสินใจในการเดินทาง เช่น การเลือกเส้นทาง การเปลี่ยนจุดปลายทาง หรือยกเลิกการเดินทาง ได้ดียิ่งขึ้น งานศึกษาถึงการพัฒนาประสิทธิภาพของระบบ ATIS มีความหลากหลาย อาทิ การวางระบบ เนื้อหาของข้อมูล ความถูกต้องของข้อมูล อย่างไรก็ดีประสิทธิผลของระบบขึ้นอยู่กับปัจจัยด้านพฤติกรรมและการตอบสนองของผู้ขับขี่เป็นสำคัญ และ พฤติกรรมของผู้ขับขี่นี้แตกต่างกันตามลักษณะของบุคคลหรือพื้นที่ (เมือง)

จุดมุ่งหมายหลักของงานวิจัยนี้เพื่อวิเคราะห์พฤติกรรมของผู้ขับขี่ในเมืองหลักของประเทศในเอเชียตะวันออกเฉียงใต้ (กรุงเทพมหานคร กัวลาลัมเปอร์ และ สิงคโปร์) ในการเปลี่ยนเส้นทางภายใต้อิทธิพลของข้อมูลการจราจรที่ได้รับและสถานการณ์เดินทางที่แตกต่างกัน โดยใช้วิธี Revealed Preference (RP) เพื่อศึกษาลักษณะของผู้ใช้ ลักษณะทางเศรษฐกิจและสังคม และลักษณะของการเดินทางที่จะมีผลต่อการตัดสินใจเปลี่ยนเส้นทาง และ วิธี Stated Preference (SP) เพื่อศึกษาการตอบสนองของผู้ขับขี่ภายใต้ระยะเวลา ความแปรปรวนของเวลาเดินทาง และค่าใช้จ่ายในการเดินทางที่แตกต่างกัน

ผลที่ได้จากการวิจัยพบว่าพฤติกรรมของผู้ขับขี่ใน 3 เมืองที่ศึกษา มีความแตกต่างกันในด้านปัจจัยที่ส่งผลต่อการเปลี่ยนเส้นทางของผู้ขับขี่ ลักษณะทางเศรษฐกิจและสังคม และ ลักษณะการเดินทาง เป็นตัวกำหนดพฤติกรรมในการเปลี่ยนเส้นทางของผู้ขับขี่ให้มีความแตกต่างกัน จากการศึกษาการเลือกเส้นทางพบว่ามูลค่าของระยะเวลาในการเดินทาง และ ความแปรปรวนของเวลาในการเดินทางมีค่าสูงสุดในสิงคโปร์ ผู้ขับขี่ให้ความสำคัญในความแปรปรวนของเวลาในการเดินทางมากกว่าระยะเวลาในการเดินทาง

ภาควิชา.................วิศวกรรมโยธา.... .... ลายมือชื่อนิสิต..
สาขาวิชา................วิศวกรรมโยธา.................ลายมือชื่ออาจารย์ที่ปรึกษา..
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Advanced Traveler Information System (ATIS) has been applied in many countries because it has been proved as one of potential solutions to solve congestion problem and to improve the quality of driving. Providing drivers with additional traffic information, it is expected to influence their travel decision on route and destination selection, or even on cancellation of the trip. A number of studies have been conducted in order to improve the performance of ATIS in various ways, such as the setting of the system, the content of information, the accuracy of the information, etc. Yet the effectiveness of the system is heavily dependent on the driver's behavior and response to the given information. The behaviors are somewhat unique for specific individuals (cities).

The primary objective of this study wais to analyze the behavior of drivers in different South East Asia major cities; Bangkok (Thailand), Kuala Lumpur (Malaysia), and Singapore (Singapore), pertaining changing route under influence of traffic information availability and travel variability situation. Users' characteristics including socio-economic and trip characteristic as well as the responses to traffic information were investigated through Revealed Preference while the responses of drivers while encountered choices between main and alternate route with different travel time duration and uncertainty, and cost properties were determined, using Stated Preference (SP) technique.

The results illustrate that the behavior of drivers in the three cities are different pertaining the factors that affect them to change the route. Their socio-economic and trip characteristics play a role in determining their route changing behavior. From stated choice study, the value of travel time and value of travel time variability can be obtained, which the highest went to Singapore drivers. Drivers appreciate reduced travel time variability than reduced duration.

Department ......Civil Engineering... **Student's signature** ....
Field of Study ...Civil Engineering.. **Advisor's signature** ....
Academic year ......2006...........

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LIST OF ABBREVIATION

ITS	Intelligent Transport System
ATIS	Advanced Traveler Information System
VMS	Variable Messaging System
IVD	In-Vehicle Device
ISB	Intelligent Sign Board
THB	Thai Baht
SGD	Singaporean Dollar
RM	Ringgit Malaysia
VOT	Value of Time
VOTV	Value of Time Variability

CHAPTER I

INTRODUCTION

1.1. BACKGROUND

Nowadays, Intelligent Transport Systems (ITS) have gained popularity in many areas in transportation field. Such new technologies have already been developed and implemented in order to improve the quality of travel and traffic conditions. One of ITS major applications, that are quite familiar to general users, is traveler information system, which is often called as Advanced Traveler Information System or ATIS. The main goal of ATIS is to give reliable and accurate information to users as an additional input to the decision-making process in devising their travel decisions. Thus, to build a proper ATIS, it is necessary to understand user's information requirement so that the technologies could provide needed and important information requested by users and later on these information could influence travel decisions.

Travel behavior is the root of why and how each individual makes decision to travel. The behavior of each person is unique since one has a unique way of intrinsic background, attitude, intention, and limitations. Many experiments in the past, for instances work done by Khattak et al. (1993) and Abdel-Aty et al. (1996), they tried to model the travel behaviors in different ways for several reasons. In the context of traveler information system, some previous studies proved that there was a close relationship between travel behavior and the introduction of travel information systems.

This research attempts to explain travel behavior of drivers under the influence of travel information (ATIS) and how it contributes in improving ATIS. The study was conducted using samples from cities in three countries with different states of development in South East Asia region. In order to achieve the purpose, the behaviors of drivers were learned and gathered through questionnaire survey and the data were then analyzed using appropriate statistical methods. The behaviors are specifically the attitude towards various traveler information systems; especially the influence of traffic information on the travel decision would be examined. A particular consideration is on the decision under travel time uncertainty. The conclusion of the study could contribute the in-depth understanding of driver's behavior (responses) under the presence and use of traffic information. The findings are beneficial to traffic system planner and operator or ITS system developer.

1.2. PROBLEM STATEMENT

ATIS has emerged to transport professionals and officials as an additional element of the modern travel and, to many people, a way to alleviate the existing traffic congestion problem. ATIS has been introduced in many areas, and benefits are reported. Since ATIS proved itself as a worthwhile solution and the upgrade of travel quality, a greater consideration on the system is placed by not only officials but also the users of the system.

Shover et al. (1993) mentioned that travel behavior was identified as the process of individual decision making regarding what trip to make, when would it takes time, where to go, what mode to use, and what route to follow. Therefore, in performing proper travel behaviors, users would need travel information (such as ATIS information) to guide them in determining the most appropriate trip decision for them based on real time condition.

To exemplify the use of travel information, people decide to divert into another route while they encounter some problems on the main route. The consideration on better ride and better saving in travel time encourage people to do so. Therefore, people need to rely on something (i.e., information) which convinced them as a proof that diverting would be the best alternative for them. This kind of information could be provided by ATIS, as the part of guiding information to commuters.

The challenges of the success of ATIS are to merge the presence of traffic (travel) information in the user's behavioral process, to provide additional and sufficient information that is useful, used, and to contribute in improving travel experience to individual users and their community. However, the reality does not speak the same facts. Some of previous research results state that ATIS information sometimes is not as effective as it should be. It just gives partial, unclear information, or even incorrect information. For example, Thakuriah and Sen (1996) stated that the information given by an ATIS system could be far from perfect.

At present, a small number of travelers have utilized traveler information system and "use" the information in their travel. Thus, the real and large-scale benefits of the ATIS cannot be realized. In fact, many people view the accomplishment of the system from the "market acceptance". For instance, Shover et al. (1993) stated that the market acceptance and driver utilization of ATIS services determined the success or failure of a particular concept and thus the success of the system then were rated low. Considering the ultimate goal of ATIS, the success of ATIS should be measured from the degree of provision of information which influences (or being used) traveler's decision. ATIS should provide valuable information, and this can be done by technological solutions. Most ATIS could provide real-time information (which is expected to be more timely and reliable), and the system could deliver information to travelers in various communication channels.

The effectiveness of ATIS system depends to not only how advance the technology is used, but also how it can deliver such useful information that can be easily digested by users. Later on, the useful information is processed by travelers to yield "proper" or "better" actions. Thus, the quality of the information provided by ATIS is essential to the success of the system and needs to be recognized as accurate and reliable, otherwise the system can bring about adverse decisions and worsen the effectiveness of travel. The ATIS system is viewed as a double-edged sword when it comes to managing traffic information (Polydoropoulou et al. 1996).

Although user perceived ATIS services are proved successful, the benefits do not appear to attract non-customers (travelers who do not buy or use the system) to motivate them seek out ATIS on their initiative. Drivers normally have their own interpretations for all traffic information based on their own experiences. They generally rate their own ability to predict traffic as reliable, and traffic information generated by radio broadcast (or other media) as unreliable. Therefore, it is impossible for them to get “more” accurate and “more” useful traffic information. As a result, there is little reason for them to buy or use any traffic information services. Then, recently ATIS services need to compete against drivers’ local traffic personal knowledge.

By experiment, the extent of benefits and risks of ATIS are still unclear because it all depends on how individual understands and uses the given information and thus assessing the worthiness of ATIS mostly depends on anticipating the behavioral responses to such technologies. From an experiment about drivers’ actual responses to message activation in London, it comes that only one third of drivers who noticed the information displayed by Visual Message Sign (VMS) and few of them were diverted, although many found the information useful. Only one-fifth of the drivers diverted compared to the expected results comes from stated questionnaire (Chaterjee et al. 2002).

These show that there are two possible reasons why the ATIS technology still has not satisfied its goal. First, the present technologies of ATIS still do not match with people needs. Alternatively, the system is good enough but people still do not conscious about the real benefit of the system. These facts are interesting to be scrutinized as one could seek the way for understanding and possible improvements. These could be answered by the investigation on travel behaviors related to the collection, process, and decision-making on traveler information system. The investigation could reveal the influence of not only the type and amount of information, but also the quality of information and the resulting decision under various traffic circumstances.

1.3. THESIS OBJECTIVES

The general aim of the thesis is to reveal the behavior of drivers under the presence of traffic information and travel time variability situation, which portrayed by driver’s change route behavior.

The specific objectives of this study are to:

a. Analyze drivers' behavior in getting travel information and what information they need most.
b. Evaluate performances of existing travel information devices and gain some ideas for the new prospect device(s).
c. Investigate drivers' risk taking behavior pertaining travel time variability and willingness to pay under influence of traffic information.
d. Compare the behavior of drivers in three different cities with different socio economic characteristics and culture.

1.4. SCOPE OF STUDY

To avoid too broad study scope and to get the accurate findings, the scope of work in this research is set as follows:

a. Respondents are limited to private car drivers who reside in the study area (Bangkok, Kuala Lumpur, and Singapore) or its surrounding area.
b. Respondents are limited to active commuters, which are drivers who drive with the same trip and relatively in the same time daily.
c. The research disregards transit riders, participants in car-pool schemes, neither those who do not drive daily (or do not have the ability to drive).
d. The focus is on respondents whose main routes are urban roads while the alternate route might be expressway and/or other urban roads.
e. The models are constructed following discrete choice modeling technique under an assumption that the data is sufficient to be modeled so and the data follows model specifications and assumptions.

1.5. OUTLINE OF THESIS

The thesis consists of six chapters that portray the process of the study sequentially. The layout of this thesis is presented as follows.

Chapter 1: Introduction

Chapter 1 consists of general introduction on the study including the objectives, the methodology and scope of study, and the expected findings.

Chapter 2: Literature Review

This chapter provides a number of past studies related to ATIS and travel behavior under the influence of traffic information. This chapter also illustrates travel behavior with travel time variability and how it deals with availability of traffic information. In the last part, the description about stated preference and analysis techniques are explained in brief.

Chapter 3: Methodology

This chapter describes the process of the survey and the properties of the survey as well. The tools that used in the analysis also described here.

Chapter 4: Survey Results

Chapter 4 contains the initial stage of data analyses, which consist of the descriptive analyses of variables that contribute in the model development.

Chapter 5: Model Development

This chapter is a detailed work of previous chapter that provides advance-modeling process of the data with discrete choice analysis (binary logit modeling).

Chapter 6: Summary of Findings and Conclusions

Finally, chapter 6 concludes this study by explaining the findings and the conclusion.

1.6. CONTRIBUTION

The underlying study attempts to show what drivers' opinions on existing travel information is and to picture the behavior of changing route due to travel variability and willingness to pay circumstances. This study expects to produce some original knowledge such as:

- Evaluation on existing travel information devices, and prosperous on-coming devices.
- Disclosure on traveler behavior that could be used in enhancing urban traffic management system, especially for travel time variability related cases.

- Since the study conducted in three different cities, the comparison could be performed in order to gain some insight on fundamental travel behaviors among cities and the knowledge could be transferred to other cities to solve similar traffic issues.

1.7. CHAPTER SUMMARY

Travel behavior regarding the use of travel (traffic) information has been an attractive subject of transportation study in the last decades. The existence of travel information recently could not be avoided, and it has made the travel behavior differ from time to time. The study is significant since it tries to find out the behavior of drivers in different situation of travel and the availability of travel information.

The research attempts to show the study framework to consider the travelers' decision with various traffic information conditions. The stated preference technique is selected as it is expected that it could produce a satisfactory prediction about how people would react into travel information presence and how it influences their travel behavior as well. The working sequences together with the summaries are described in detail in the succeeding chapters.

CHAPTER II

LITERATURE REVIEW

2.1. INTRODUCTION

In order to support the undertaken study, a review of related literature was performed. This chapter was divided into five subsections. After the introduction, the reviews in Intelligent Transport Systems (ITS) and Advanced Travel Information System (ATIS) were presented. Next, some studies regarding travel behavior under influence of ATIS in particular were reviewed as well. Moreover, the theoretical frameworks for Revealed and Stated Preference techniques were discussed. Lastly, data processing and analysis methods for developing a travel behavioral model were presented.

2.2. OVERVIEW ON INTELLIGENT TRANSPORT SYSTEM (ITS)

2.2.1. General

The introduction of new transport technologies has been of interest in the field of transportation theory and practice. New development and implementation of new technologies opens up the door into modern transport system. Numerous applications of new technologies in wide range of transportation facets have led the world into better transport system operations, both private and freight travel.

Intelligent Transport Systems (ITS) has been given attention in managing urban traffic flow, improving the efficiency of freight transport, also helping to enhance traffic safety. Referring to the definition by Sayeg (2006), ITS is a merging technologies between computing system, information and telecommunication technology to automotive and transportation sector expertise. In other words, ITS can also be defined as the application of computing, information, and communication technologies into real-time vehicle management systems and networks which involve the movement of people and goods. The users of ITS technologies can be identified as three major components, as follows:

a. Infrastructure

   Traffic lights, traffic detectors, traffic information computing systems, toll gates, etc.

b. Vehicles

   Model of vehicle, safety features, their degree in application of advanced technology, etc.

c. People

   Pedestrian system, traveler information system, etc.

ITS serves people in many aspects of transportation and can be summarized into eight priorities of user services as illustrated in Table 2.1.

Table 2.1 ITS users' services

User service bundle	User service
Traffic management	Transportation planning support Traffic control Incident management Demand management Policing/ enforcing traffic regulations Infrastructure maintenance management
Traveller information	Pre-trip information On-trip driver information On-trip public transport information Personal information services Route guidance and navigation
Vehicle systems	Vision enhancement Automated vehicle operation Longitudinal collision avoidance Lateral collision avoidance Safety readiness Pre-crash restraint deployment
Commercial vehicle	Commercial vehicle pre-clearance Commercial vehicle administrative processes Automated roadside safety inspection Commercial vehicle on board safety monitoring Commercial vehicle fleet management
Public transport	Public transport management Demand-responsive transport management Shared transport management
Emergency management	Emergency notification and personal security Emergency vehicle management Hazardous materials and incident notification
Electronic payment	Electronic financial transactions
Safety	Public travel security Safety enhancement for vulnerable road users Intelligent junctions

Source: Sayeg (2006)

As shown in the table above, there are eight user service bundles of ITS applied in the transport areas. Each user service bundle has their own preferences and the applications of advanced technologies in each bundle are expected could boost its productivity and performance in their sectors so it will generate a more efficient and sustainable transport system in the future.

In general, developing cities are struggling to manage their contradictive traffic congestion problem. This condition is caused by a high number of vehicles in the roads because of the significantly high economic growth rate of developing countries. Numerous transport facilities infrastructure have been built, but unfortunately, it cannot catch up with better driving conditions. On the other hand, developing cities tend to have various public transport modes, from buses to mass rapid transit with a range of facilities offered as well but poorly managed by government. As expected, traffic congestion would always be major urban cities' nightmare. In reaching sustainable transportation, there are such priorities in applying ITS for each user service bundle, especially for developing areas.

2.2.2. Advanced Traveler Information System (ATIS)

Advanced Traveler Information System (ATIS) is a subset of Intelligent Transport System (ITS) technologies and defined as a system that provides real-time information to travelers about traffic conditions, delays, transit schedules, parking availability, roadwork, and route guidance from origin to destination (Polydoropoulou et al. 1996).

Real time information allows traveler to make informed decisions and has the potential to improve the network, efficiency, reduce congestion, and enhance environmental quality as well (Dia et al. 2001). In fact, these systems (ATIS) are proved useful for users in disseminating such beneficial traffic information that helps drivers to make better travel decisions prior to and/or during their trips for their own convenience, and giving information about public transport on the predicted arrival time or sources of delay.

However, this information should be provided far enough in advance of critical decisions point for drivers so they have enough time to evaluate their alternate actions, to make proper travel decisions, and to perform some actions to help reduce their individual travel time.

The framework of ATIS system is simple. First, situations are gathered from the field using a variety of high-technology equipment located along selected corridors such as traffic sensors and cameras or even equipment attached on vehicles such as Global Positioning System (GPS). Furthermore, the data are sent to the traffic center and using powerful software, the collected data are interpreted into beneficial real-time traffic information and then disseminated to the commuting public via accessible channels such as television or radio reports, telephone, newspapers, websites, Variable Message Sign (VMS), or even in-vehicle devices. Receiving the information, commuters are expected to respond by altering their travel behavior. This process can be explained in Figure 2.1.

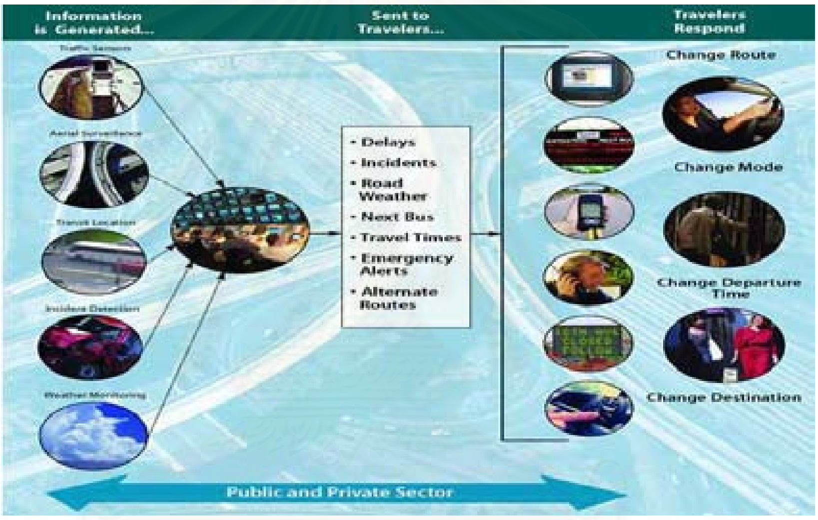

Figure 2.1 Traveler Information System (http://ops.fhwa.dot.gov)

In the real world, features of ATIS can be either pre-trip or en-route (or both) and either for public transport users or private vehicle drivers. This information is used for commute trips to avoid congestion or for recreational trip to find nearby attractions. Toppen et al. (2002) stated that ATIS had the potential to benefit drivers in reduced travel time, reduced stress level caused by traffic congestion, and it could lead to cancellation of trips as well.

The performance of ATIS is highly dependent on driver behaviors. This phenomenon comes up in consequence of the main goal of ATIS to maximize the network performance by reallocating or shifting travel demands in proper proportion. Therefore, to achieve the desirable shifting of travel demand, the solid and accurate system and positive driver's responses to ATIS information are highly required. Thus, to build an effective ATIS, it is important to provide good quality of data accumulation. The characteristics of ATIS, information, communication, and integration are the key features of ATIS. Besides, it is critical to have better understanding on driver's behavior so the information passed to drivers can be digested and results in actions that yield "more efficient "travel.

2.2.3. What Do People Need From ATIS?

In general, drivers who drive regularly (have prior knowledge on travel condition on the route) tend to respect their own experience more than other sources. As a result, some drivers would prefer to believe their own experience and judge other sources to be inaccurate, unreliable and useless information while others think there are no alternatives for traffic congestion and no use on traffic information. Derived from this condition, ATIS are facing a tough challenge in giving its services to the public. The services are competing against driver's personal traffic condition knowledge, and trying to disprove driver's belief of traffic information unimportance.

On the other hand, consumer's expectations of ATIS service in general are relatively high. Despite of the doubts of traffic information values, most commuters realize that there are possibilities for them to change their route due to unexpected incidents. Real time information holds a big role in creating a great ATIS demand. When commuters need suggestions of re-routing, they depend on ATIS in acquiring information. Since the commuter trip seems unpredictable (as afternoon trip are harder to predict than morning trip), drivers tend to look for additional traffic information by searching in the internet, listening to radio or television traffic reports or even other advanced equipment. This shows the needs for traffic information by these groups of people.

Several channels can be used to connect traffic information to travelers. Internet and television reports provide pre-trip traffic information that helps people accessing them from their houses or before leaving the offices while radio broadcast can provide both pre-trip and en-route traffic information. Some traffic information is displayed by devices (e.g. VMS) installed on specific places on the roadside, or drivers could make a phone call to a traffic information center to ask for further information. Furthermore, some people tend to buy an additional in-vehicle device that allows them to get complete traffic information anytime and anywhere.

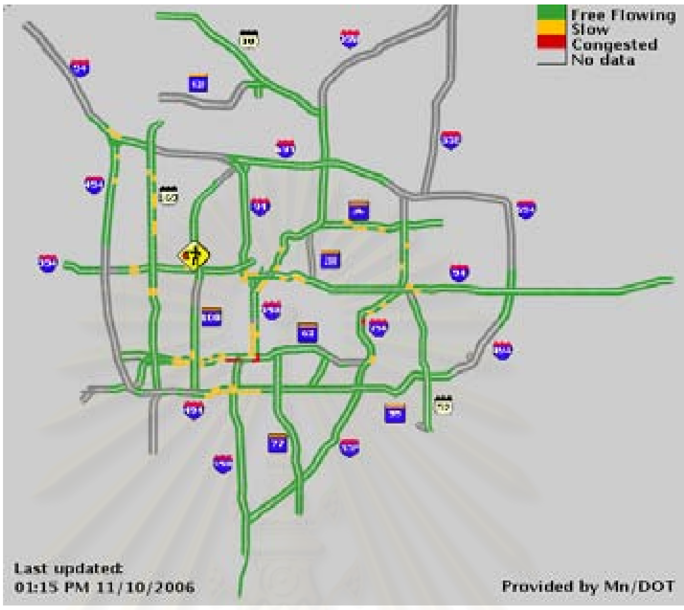

Figure 2.2 ATIS Traffic Map (http://www.dot.state.mn.us/)

There is a pattern of growth in driver's expectation to ATIS to provide better services. As the result, to provide more reliable, variable, and accurate information is the main objective for every ATIS provider.

2.2.4. Reasons for Using ATIS

Drivers utilize ATIS to assist them reduce uncertainties of their trip. For some areas that suffer from traffic congestion, demand for ATIS is likely to be great because each driver wants to lessen the impact of traffic congestion delays and improve their journey. Thus, for regions with lesser congestion the demand would be smaller. The Washington State DOT traffic website narrows down reasons why people use ATIS services into five purposes, listed in order of importance:

a. To assess traffic congestion on their route,

b. To judge the effects of incidents on their trip,

c. To decide among alternate routes,

d. To estimate their trip duration, and

e. To schedule their trip departure.

In general, drivers who use ATIS experience changes in time of departures, route of travel, trip mileage, and even duration of the trip itself. They also have a tendency to be well prepared for some unavoidable congestion, for instance preparing entertainments in the vehicle (in case they are trapped in congestion), adjust their expectations, adjust appointments, and make some alternative arrangements (Lappin, J. 2000).

The use of ATIS gives four primary benefits to drivers in order of importance such as:

a. Time saving,
b. Lesser or none congestion experience,
c. Stress reduction,
d. Avoided unsafe conditions.

2.2.5. Critical Features of an ATIS Traffic Service

After installation of ATIS systems for some time, various opinions were raised regarding their performance. There were not only compliments but also some critics as well. In the US, some qualitative field service was conducted by the WSDOT ITS program in 1991[1] in various traffic information concepts in some designated ATIS regions. It was found that people really concerned about:

- Accuracy,
- Timeliness,
- Reliability,
- Cost (installment and operation),
- Degree of decision guidance and personalization,
- Convenience (of access), and
- Safety (in operation).

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[1] From May 11 through June 8, 1999, a banner on the WSDOT traffic web site invited users to participate in an on-line survey to help improve the web site. A total of 608 users completed the questionnaire.

Issues related to design of ATIS services were:

- Would drivers rely on real time traffic information and would they follow suggestion on diversion from their regular route?
- What information should be given in advising people to detour?
- At what level of increased travel time should be provided when advising drivers to divert?
- What differentiates drivers who were more or less likely to divert?

2.2.6. ATIS Evaluation Method

Evaluation of ATIS is essential since the system is built to satisfy its consumers and to yield overall benefits. To evaluate ATIS performance, goals of the evaluation must be set first so that the benefits of the technologies can be measured. Several techniques can be used in evaluating ATIS performance, as they can be categorized into three categories: field studies, simulation, and surveys.

Generally, field studies involve putting drivers with or without ATIS in the roads and determining the differences in travel times between them. When simulation shows the potential benefits that could arise if ATIS was used at certain locations, survey studies are conducted to focus on ATIS users to determine what ATIS benefits they perceive both qualitatively and quantitatively.

The main idea of survey studies is to involve the public poll about a particular technology, including whether they know it exists, what they perceive from it and what they are willing to pay for certain technology. Surveys are typically classified into two sub-categories, user perception and willingness-to-pay (Kristof, T. and Lowry, M. 2005). The perception study is more to qualitative approach while Willingness-to-pay (WTP) study is more to quantitative approach.

User Perception

A number of studies conducted surveys which respondents were required to explain how ATIS helps them in saving their travel time, reducing anxiety caused of traffic jam, or even optimizing the usage of their time. Kristof and Lowry (2005) cited some important past studies, Ullman et al. (2000) focused on SmarTraveler benefits in Boston in the late of 1990s. Yim (2000) studied TravInfo system in San Francisco for traffic websites, while Khattak et al. (1995) and Polydoropoulou et al. (1995) studied modeling RP and SP of pre-trip and en-route ATIS travel response. From those studies, the results indicate that ATIS could assist some of drivers to improve their driving experience by changing route, avoiding congestions, saving time, and even reducing stress and anxiety.

Typically, traditional formats of user perception surveys produce the results that cannot be easily generalized, and they do not allow for calculating quantifiable benefits (and thus evaluation). In general, the user perception surveys try to reveal driver satisfaction. However, quantifying perceived time saving is still a major task for the study improvement. Kang, et al. (2005) studied about benefit quantification of VMS in Korean National Highway Network using Integration and ITS Deployment Analysis System (IDAS). In the research, they mentioned that it was not easy to study the diversion ratio with given traffic information, even after the drivers were furnished with traffic information. Jung et al. (2003) mentioned that, while users experienced a potentially great time saving, the actual time saving might be minimal or not as much as they expected.

Willingness-To-Pay (WTP)

Willingness-To-Pay (WTP) is mostly obtained by conducting Stated Preference (SP) type of survey, in which people are surveyed about what they would do under particular hypothetical scenarios. Different studies may yield different results as well. Polydoropoulou et al. (1997) studied about WTP on SmarTraveler in Boston area that target to users and non-users. The service was free and the respondents were asked whether they wanted to pay for the service under two different pricing scenarios: monthly service charge and a per-call service charge. While the WTP studies offer understanding of how much people spend and value the system, often what people think and what they really do are different. This issue makes WTP survey arguable when the method is used for measuring the benefits.

So far, many different approaches for measuring benefit of ATIS have been conducted by field studies, surveys, even simulation methods, including survey on perceptions and willingness-to-pay. Though all of these methods give a means for evaluating ATIS technologies (benefits), some of the techniques may have become obsolete, or costly, or even difficult to adopt in other metropolitan areas.

2.3. TRAVEL BEHAVIOR

2.3.1. General

The present studies of ATIS focused in improving and validating the framework for assessing the impacts of ATIS technologies in penetrating traveler behavior (decision) in an unexpected delay situation (Ben-Akiva et al. 1994).

Drivers drive for a specific purpose; go to work, travel to social, recreational or business events, or meet colleagues. A driving strategy chosen by a driver to reach their destination is dependent on his accumulated experience, his knowledge of predicted journey time and traffic information. The modern technology has allowed customized and personalized information to be delivered to drivers, whenever and wherever they want. Emerging access to VMS, web cameras, web sites, and mobile telephone messaging has made increasing possibilities of drivers to get customized information.

The behavioral model generally uses socioeconomic characteristics of drivers in explaining the travel behavior. Travelers receive traffic information through some media (electronic and non-electronic) and self-observation. The information can be delivered in many ways and perceived in various channels as well. Drivers appear to possess various characters, whether good or bad, passive or aggressive, noticeable or ignorant, knowledgeable or first time user, etc. They interpret the information in relevance with their own knowledge on perceptions of travel time and delay. The rate that drivers could learn and interpret the information varies as well. Some drivers are fast learners and need specific details; others are slower and sometimes misinterpret the information that generally requires only broad explanation. Perceptions, restrictions, and individual's characteristics determine preferences for certain alternatives. The preferences also depend on previously obtained occurrence. If the experienced delay goes beyond the threshold of tolerated time, then this delay experience may change the travel preferences in the future, for example drivers may depart from home earlier when they anticipate (or experience) previous congestion. The changing preferences also lead to an outcome, if the outcome is satisfactory so the behavior will be repeated. The outcomes also provide feedback to update the knowledge. However, in unexpected delay incidents, the anticipated outcomes are often unsatisfactory and have a high degree of uncertainty, which leads in triggering a review of preferences and changes in travel patterns.

Various aspects influence traveler's decisions and availability of traffic information is one of them. Before the availability of ATIS that could spread away traffic information, people depend on just their own knowledge for their trip. A major route will always be the primary choice by its (perceived) effectiveness on a saving in time and money, considering the comparison of the advantage over one or more alternate routes. The route decision forced to be made only when there is something wrong, or unexpected, on the main route. The main problem is that people do not have abilities to know the real traffic condition on the main and alternate routes. The decision is made based on uncertain data about route conditions and thus the rightness of the decision is a matter of possibility. It is also a chance for drivers to be caught in traffic congestion or an unexpected incident, when the decision is wrongly determined. It is believed that, with real time information, one can conduct proper driving behaviors and with anticipation, the overall traffic would benefits from the organized behaviors.

2.3.2. Travel Behavior Considering Travel Time Variability

Major variable in the route choice decision is the travel time (delay) on both regular and alternate routes. These travel times are naturally uncertain. Indeed, drivers need to plan their journey by determining the right departure time considering extra delay factor. Each driver has his/her own delay threshold. While en-route, when drivers face an effect on uncertainty (e.g. accident), they have to make prompt actions whether changing route or stay on the route.

Moreover, drivers deal with not only the uncertain amount of travel times on regular and alternate routes, but also the decision process with “risk”. The estimated travel time is uncertain, and the future travel time (as projected from now) is uncertain as well. Travelers do not know the priori conditions if there will soon be any heavy congestion, or they should divert the route or not. In general, travelers do not know the consequences of their travel decisions in certain ways. They can just try to predict and expect the probabilities associated with an (current) expected amount of travel time. This probability associated with the outcomes can be called as a risky situation. Nonetheless, some researchers, such as Senna (1993), have called it “uncertain situation”.

A negative effect of congestion that tends to be overlooked is travel time uncertainty. Travel time uncertainty (or travel time variability) is an added cost to a traveler making a given journey, or can be simply interpreted as added travel time in terms of delay. In addition, it causes scheduling cost due to early or late arrival. Travel time variability includes differences in travel time in day-to-day basis, over the course of the delay even from vehicle-to-vehicle (R. B. Noland and J. W. Polack, 2002). Most researchers focus day-to-day difference basis since it is important in determining independent congestion effects.

Furthermore, evidence on the behavioral response to travel time variability has also been investigated by analyzing route choice decision. Although it may be reasonable to assume that travel time is the most important factor to evaluate route choices, but it is not always acceptable to assume that travel times are deterministic and exactly known by travelers. Travel time is influenced by various factors. Some of the variability in travel time are caused by supply-side effects, such as reduction in capacity due to traffic accidents, scheduled road maintenance, or transport systems failure. Demand side events such as irregular events (e.g., sport events) may cause travel time variability as well. The variation in the capacity to volume ratio even in a small amount may lead into great travel time variability. Moreover, the causes of travel time variability may be partly due to the traffic system operator actions, such as traffic signal re-arrangements (Avineri and Prashker, 2003).

The availability of traffic information is expected to reduce uncertainty and to assist the learning process. Traffic information improves travelers' estimate of the expected travel time, which will lead to reducing scheduling costs. Avineri and Prashker (2003) studied the influence of providing dynamic travel information. The result indicated that the availability of information influenced the propensity of a route to be chosen, although it was not the reliable route. Provided with traffic information (i.e. travel time), people tended to prefer the route that was on average worse but more certain more frequently (or less variability) to the route with no information at all (or in other words unknown variability).

In the analysis of travel (route) choice behavior problem, Lotan and Koutshopulos, (1993) divided the uncertainties into two different types. One was the randomness due the non-deterministic nature of route choice behavior, and the other was the vagueness due the lack of familiarity with road networks and the linguistic information of the network attributes.

Considering the consequences of the travel time variability, the route changing is probably the best action that a driver can think of and respond to avoid the congestion. One of the reasons that people do change the route is that people obviously tend to avoid non-recurrent traffic congestion compared with recurrent traffic congestion. This also implies that providing information on the cause of the congestion is significant for drivers. Moreover, people tend to choose routes that are free from congestion so they can enjoy their ride even though the distance is longer compared to the original route.

2.3.3. Drivers Behavior and Response to ATIS

Since demand models play a central role in improving ATIS performance. Indeed, the impact and response to such technologies must be captured, understood, and explicitly predicted. Numerous researches have conducted to investigate each context of ATIS applications. Most recent methodologies for the evaluation and management of ATIS are based on travelers' behavioral model, predicting the response of users to the ATIS systems.

A study by Mahmassani and Yu-Hsin Liu (1999) was concerned about driver's response in commuting behavior under influence of ATIS. The results regarding drivers' behaviors came up with these explanations below:

1. Older commuters showed a greater tolerance to scheduled delays in pre-trip departure time switching than younger ones. In addition, female commuters showed a wider range of indifference compared to male commuters for pre-trip departure time as well as en-route path switching decision.
2. Reliability of real time information was a significant variable in determining commuters' pre-trip departure time and en-route responses. Reliability would affect the decision to change the departure time (whether the reliability was low or high) instead of keeping the routine departure time.
3. Commuters were persuaded to greater scheduled delay if they had recent experiences in travel time increase because of small adjustment in departure time.
4. Commuters tended to switch their route both pre-trip and en-route in response to differences between predicted arrival time and their own predicted arrival time. Furthermore, they tended to switch their route if they experienced late arrival by following the current route.

As mentioned before, a series of travel decision would come up as a result after getting traffic information, whether it is changing route, changing departure time, or even cancellation of the trip. These actions happened mostly because drivers want to minimize their travel time. In addition, several researches prove that many other factors such as safety, comfort, and scenery influence the travel decision as well. The preferences of each driver in determining their decisions are vary. A study conducted by Abdel-aty (1990) resulted that commuting distance, gender, education level, and familiarities of the route are some of factors that make the difference in commuter behavior besides availability of traffic information. Bonsall et al. supported the statement by saying current knowledge will influence route changing up to 80%. Then, they added that factors affecting driver's response to VMS are driver's abilities to read the signs, to understand the information, to recognize whether the information is relevant to their needs, and to address their credibility to the message. Furthermore, Eric and Peter (1998) found that driver habits also influence the travel choice. Then, the more information provided the more it influences the effort in determining their route choice.

2.3.4. Variable Message Sign (VMS) Studies

VMS is one of the most common deployed ATIS devices, which has been widely used to disseminate traffic information in many roadside locations. VMS systems are usually installed on the side or over the roads to display the real-time traffic information such as congestion ahead, incident report, or existence of construction work. One of the ultimate goals of VMS is to maximize the performance of the network by reallocating travel demand (Lee et al. 2002).

Figure 2.3 VMS in Siam Square Area, Bangkok (*author*)

Typically, VMS messages are only beneficial in abnormal or unique situations. Furthermore, VMS impacts on diversion rates are often modest since the information is openly disseminated to all drivers who share the same routes. The common goal of VMS studies is how to study drivers' behavior while they have to share the same displayed information. A driver will make a travel decision based on his own decision, and consideration of other drivers' responses as well.

There are two main approaches in VMS studies. First, the empirical studies that are conducted through various surveys and the second groups are the drivers' behavior model development. Various studies attempted to focus on traveler behavior under VMS and these kinds of investigations are quite popular recently. Bierlaire et al. (2006) studied about drivers' responses to VMS in Switzerland and came up with a behavioral model using discrete choice approach for pre-trip and en-route type of information. Chaterjee et al. (2000) focused on building a driver response model to VMS in London area. Another study by Hounsell et al. (1998) was about the evaluation of VMS in London under CLEOPATRA (a telematics project in the European Commission's Fourth Framework program) research project. The study evaluated the VMS performance and came up with the result by providing more updated unpredicted incident information would be more meaningful to drivers. The famous study in VMS conducted by Wardman et al. (1997) reported that the impact of VMS was dependent on the content of the message, drivers' characteristics, and previous network knowledge. Then, drivers would become more aware to delay since it exceeded the tolerated threshold.

2.3.5. In-vehicle Device Studies

Aside of VMS, which is located on roadside and provides traffic information to general traffic, the in-vehicle device is another type of channel for information dissemination and is gaining popularity in giving personal en-route traffic information to drivers. Several services and features have been promoted by traffic information providers with various packages and with various prices as well.

This kind of device is quite popular in developed countries such as European countries or even Japan; there are many productive researches in this subject. This device is believed that it could provide specific and necessary information to drivers, and thus has a high potential that the decision of individual can be optimized and the goal of overall traffic congestion solution can be easily realized.

Figure 2.4. Dash Express^{TM} in-vehicle navigation device *(www.dash.net)*

The most popular feature is in-vehicle navigation that gives drivers route navigation or route guidance. Another popular feature is urban traffic flow information, which informs drivers the distribution of traffic in the city so they can easily know which roads are suffered from congestion, and which roads are vacant so they can divert themselves accordingly. Besides, in-vehicle traffic information device also offers features as incident information, route guidance, weather report, et cetera.

Studies regarding this device were mostly concerned with one or two different point-of-views. Some studies were concerned about the system, and the other emphasized in users' behavior towards the information. For users' behavior studies, they tried to ensure whether in-vehicle devices could provide information that was relevant with driver's needs in practical form. Many of these studies focused on analyzing driver's preferences of the information (Mannering et al. 1995), the value of traveler information for drivers (Levinson, 2002), or even the impact of the device to drivers (Shiaw-Tsyr Uang and Sheue-Ling Hwang, 2002).

Cited from Lappin (2000), Schofer et al. (1997) studied about Dynamic Route Guidance (DRG) and found that there was a variety of perceptions by drivers on DRG. First, women drivers preferred DRG while men drivers preferred delay advisory feature. Moreover, most drivers believed that, in their local area, they could find an alternate route by themselves better than any device suggestion. The rest believed that they had their own delay (tolerance) limit, then received and believed any suggestion from DRG whenever the traffic (delay) condition exceeded the limit. Finally, drivers had a greater acceptance on DRG information when they reckoned that the system provided good advice.

Beside the type of information, drivers also want reliable, accurate and relevant traffic information while driving. For many trips, the in-vehicle device provides information that is already out-dated by the moment they reached the decision point of potential route diversion. This is where the greatest demand of ATIS lies. Drivers recognize the safety challenge when the information is delivered to them. For example, in the previous study resemble to the use of in-vehicle device, most respondents expressed safety concerns about mobile phone usage when driving. This problem would occur to all in-vehicle devices, including the navigation device.

2.3.6. Intelligent Sign-Board Studies

Started from March 2005, Bangkok has introduced a new message board, known as Intelligent Sign Board, which consists of colorful panels informing drivers of the bad traffic on major urban roads. Three colors; red, yellow (or orange) and green, represents the traffic condition on associated routes showed on the board. This kind of board would be introduced in the others location and expected to gather the public response regarding this device as well.

Figure 2.5 Intelligent Sign Board in Pathumwan intersection, Bangkok *(author)*

This system was a part of “Intelligent Traffic System” which includes electronic road signs, GPS-equipped buses, taxi stands linked to call centers. Bangkok’s roads and public transport systems are to benefit from five high-technology projects this year, collectively called “the intelligent traffic system”. Its aim, once more, is to relieve traffic congestion, so Bangkok people would spend less time on the roads. The intelligent traffic systems were also expected to provide comfort to drivers and mass transit commuters as well as promoting the use of mass transportation systems.

Some of the technologies were imported and others developed locally, and the most proud thing is Bangkok would be the first city in the world using them all together. Forty “intelligent traffic signs” were installed in front of expressways and important intersections by June 2005 and they provide real-time information on graphic maps, informing drivers about crowded roads and traffic accidents (The Nation, published on March 14, 2005.

This intelligent signboard is already installed in several places in Bangkok. For instances, we can find it at Din Daeng end of the Uttaraphimuk (Don Muang) elevated toll-way connecting to the Second Stage Expressway, Silom Road, Petchaburi Road, and Pathumwan intersection as seen on the Figure 2.5 above. However, since the technology is relatively new, studies related to the performance of the signboard were still on progress.

2.4. REVEALED AND STATED PREFERENCE TECHNIQUES

2.4.1. Introduction

For studies involving responses from people, two techniques, Revealed Preference and Stated Preference, are well known and widely used for developing a behavioral model. Revealed Preference (RP) data are commonly used by marketing, economic, and transport matters to estimate models that explain discrete (or individual) behaviors. Such data may have substantial amounts of noise because of numerous influences, for example measurement error. On the other hand, Stated Preference (SP, in some references called as stated choice) data are generated by some systematic and planning design in which the attributes and their levels are pre-defined without measurement error and varied to create preferences or choice alternatives.

In general, RP data contain information about current conditions and it can be used to forecast short-term conditions. In contrast, SP data are especially rich in attribute trade-off information, but may be affected by the degree of contextual realism established in the questionnaire.

Stated Preference techniques are based on the presentation of hypothetical conditions given by researchers to a number of respondents, and the scenario have to be realistic and plausible enough to be useful for studying non-existing market research such as improving public transport services or applying road pricing policy.

2.4.2. Difference between Revealed Preference and Stated Preference

To distinguish both methods, typical characteristics of each technique can be listed as below:

RP data typically:

a. Represent the world as it is now (current/existing condition),
b. Have inherent relationship between attributes,
c. Have only existing alternatives as observable factors,
d. Represent market and personal constraints on the decision maker,
e. Have high reliability, and
f. Yield one observation per respondent at each observation point,

SP data typically:

a. Describe hypothetical or virtual contexts,
b. Control relationships between attributes, which permit relations of utility functions with technologies different from existing ones,
c. Can include existing and/or proposed and/or generic choice alternatives,
d. Cannot easily represent changes in market and personal constraints effectively, and
e. Usually yield multiple observations per respondents at each observation point.

The RP method is involved with the collection of actual travel conditions collected by asking respondents with several questions related to their experiences on various dimensions in the real situation. However, RP techniques have some limitations; such as:

1. Lack of variation of actual choices (which leads to difficulties in constructing good models for evaluation),
2. Difficult in distinguish the relative importance of other variables, and it is not suitable for obtaining responses in brand new policies purpose,
3. Observed behaviors are dominated by certain factors and may not reflect the real behavior,
4. Difficult to detect the relative relationship between variables used, and
5. Difficult to acquire public opinions about entirely new regulations.

2.4.3. Characteristics of SP Techniques

The SP technique has a freedom to design wide varieties of scenarios that are suitable for various research requirements. This power has to be balanced by the realism of the hypothetical situations so that respondents would give answers in realistic ways as well. Furthermore, because SP experiments are statistically efficient, samples are typically smaller than comparative RP studies (Ortuzar and Willumsen, 1994). On the other hand, the problem of sample representative may be complicated in SP because of the additional flexibility offered by the approach. People would give the most reliable responses when they were asked to consider simultaneous changes in up to three facts only.

The main advantages of SP techniques over RP techniques are that some major problems related with RP data can be avoided in SP techniques. All respondents can be offered by attractive choices and range of trade-offs than RP data. In brief, SP technique gives more spaces to researcher to widen their scope of interest. Another strong benefit of SP technique is that it allows trade-off between various attributes in its alternatives. In order to optimize the efficiency of SP design, attention should be put in the condition that choices intend to change. When it involves trade-off, there will be respondent’s relative valuations between two alternatives. This valuation can be called as ‘boundary values’.

Moreover, RP survey requires quite large number of respondents to get accurate estimates. In contrary with SP survey which requires a smaller number of samples because typically SP surveys are statistically efficient (Ortuzar and Willumssen, 1994). Apart from the consideration on which type of SP survey should be used, the data collection method (ranking, scaling, or choice) has been another important issue in SP survey. Methods of SP survey can be identified into three main types:

a. Ranking Method

Respondents are asked to order ranks for given scenarios by their preferences, from the most attractive to the less attractive ones. The hypothetical scenarios vary by their levels of variables. The data will be strongly ordered, and provide a complete preference order, albeit with no information about preference degree or differences. Rankings offer richer data because of the higher measurement scale used. However, it is arguable that ranking SP methods may represent a more sensitive approach than choice exercises of the relative importance.

b. Rating Method

Rating techniques involved with the questioning to respondents to express their degree of preferences by labeling a number of scales (usually ranged from 1 to 10) into particular scenarios. In this case, respondents are allowed to express their degree of preference between two options in semantic scale, typically in five points. Rating is attractive for respondents but its result sensitive to the numerical (or probabilistic) values of semantic scale offered to individuals to indicate their preferences.

c. Choice Experiments

In choice experiments, respondents are required to select an option either from a pair or from a group of choices. The respondents are only asked to choose their preferred option, thus expressing their preferences in a form corresponding to an RP survey. In order to increase the realism, there is a possibility for respondents to choose neither of the choice to avoid bias by choosing unacceptable choices.

All methods require individuals to consider the solutions or preferences of given set of choices under hypothetical situations. Ranking based method requires individuals to rank their preferences based on its attractiveness; rating based individuals are asked to indicate the strength

The following errors that might occur to all types of SP data include:

a. Respondent fatigue, the interviewers need to maintain respondents' interest in answering series of questions.
b. Policy response bias, might occur when the respondents are more interested in affecting the outcomes of the analysis.
c. Self-selectivity bias, occurs when respondents either accidentally or on purpose, cast their existing behavior in better terms.

2.4.4. Discrete Choice Theory

2.4.4.1.Theories of Individual Behavior

In general, practitioners are always interested in the behavior of a large number of people expressed in terms of aggregate quantities such as market demand for any goods or services (Ben Akiva and Lerman, 1985). However, the fact is, the behavior of a number of people is a result of each individual's decisions.

In travel behavior research, researchers are just interested in the theory of individual's decisions, which have some important properties such as:

a. Descriptive, it explains the behaviors of human being but does not prescribe what they ought to behave.
b. Abstract, it can be described in terms that is not in particular and specific situation.
c. Operational, it results with models that can be measure or estimate the parameters.

In choice problem, people are offered with a number of available alternatives although sometimes they are not even aware of it. Then, he or she may have a specific sequence of decision-making process. Theory of choice behavior cannot be separated from its primary elements, such as; **decision maker, alternatives, attributes,** and **decision rule**. For instance, when people (decision maker) wanted to choose whether they would like to use bus, transit, or private car (alternatives) for their commuting activity, they would consider the strong and weak point of both options (attributes of alternatives). The consideration concern about dominance, satisfaction, lexicographic, and utility factors (decision rule) of the options that will lead to choose which mode that benefits them most.

Instead, although choice based samples can be quite economical in collecting pertinent information at low cost, but it is sensitive to produce biases since minor variations in survey procedure can result in differences in statistical analysis attributes and differences in the measured attributes of the alternatives. (Ben-Akiva et al. 1997)

Therefore, the study on traveler's behavior (under the influence of ATIS) would follow a general framework of choice theories, and some common assumptions used for these theories can be identified. The study follows classical economic consumer and discrete choice theories, which introduces a single objective function called a utility term. Utility is defined as the attractiveness of an alternative expressed by a vector of attributes value which reducible to a scalar. It assumes commensurability (changeable feature) of attributes. Utility maximization theory states that a consumer behaves as if he/she were maximizing his/her utility level. For example, if known that $U_A > U_C$, it means that consumers prefer A to C. There are two types of utility, constant utility and random utility, which have a significant difference in its utilities of alternatives. For constant utility, the utilities of alternatives are fixed while in random utility it cannot certainly known and it has a randomness feature. As in consumer theory, which is illustrating the transformation of desires assumption into demand function in order to express the action of a consumer under given specific circumstances. With the analogies of this, one can model the consumer behavior on choosing alternatives into utility model as shown below:

$$U_{in} = V_{in} + \varepsilon_{in} \tag{2.1}$$

Where: U_{in} = Utility of alternative i for individual n

V_{in} = Certain variable of alternative i for individual n, and

ε_{in} = Uncertain/unobserved variable of alternative i for individual n.

An important property of this discrete choice theory is the Independence from Irrelevant Alternatives (IIA). This property can be described, as *the ratio of the probabilities of any two alternatives is independent from the choice set*. Referred to Ben Akiva and M.Lerman (1985), this can be easily shown as follows:

$$\frac{P_n(i)}{P_n(l)} = \frac{e^{V_{in}} / \sum_{j \in C_n} e^{V_{jn}}}{e^{V_{ln}} / \sum_{j \in C_n} e^{V_{jn}}} = \frac{e^{V_{in}}}{e^{V_{ln}}} = e^{V_{in} - V_{ln}} \qquad (2.2)$$

Where $P_n(i)$ = probability of alternative *i* to be chosen

Validity of the choice axioms depends on the structure of the choice set which is restricted to choice sets with distinct alternatives. On the other hand, random utility characteristics are also applied in this theory of choice probabilities. Under these characteristics, the choice selected must have the highest utility function to others, as shown in the equation (2.3) below.

$$P(i|C_n) = \Pr[U_{in} \geq U_{jn}, \forall j \in C_n) \qquad (2.3)$$

With n represents individual person with choices between *i* and *j* under choice set C. Each utility (U) is a function of certain/observable component (V) and uncertain/unobserved component (ε), which more popular called as disturbances.

2.4.4.2.Binary Choice Model

General

In binary choice model, there are exactly only two alternatives in one choice set, and it deals with utility rather than physical weights, and say that observed utility = mean utility + random term. The characteristics of the alternatives (in) must be considered, so we have $U_{in} = V_{in} + \varepsilon_{in}$.

The choice set is denoted by C_n {i,j}, then probability of any alternative *i* being selected by person n from choice set Cn as shown in equation (2.3).
By ignoring the probability that $U_{in} = U_{jn}$, one can also write down the equation above as:

$$P_n(i) = \Pr(U_{in} \geq U_{jn}) \qquad (2.4)$$

Which is the probability of choosing alternative j is $P_n(j) = 1 - P_n(i)$.

Recalling than U_{in} and U_{jn} are random variables, one can explain the two alternatives as follows:

$$U_{in} = V_{in} + \varepsilon_{in}$$
$$U_{jn} = V_{jn} + \varepsilon_{jn} \qquad (2.5)$$

Where V_{in} and V_{jn} called the systematic components of the utility of i and j and assumed to be deterministic (i.e. non random), ε_{in} and ε_{jn} are the random parts and are called the disturbances (or random components).

As one rewrites the equation (2.4) above

$$P_n(i) = \Pr(U_{in} \geq U_{jn})$$
$$= \Pr(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn})$$
$$= \Pr(\varepsilon_{jn} - \varepsilon_{in} \geq V_{in} - V_{jn}) \qquad (2.6)$$

For each V, it can consist of more than one linear parameters (and linear in parameter V) which denoted by $\beta = [\beta_1, \beta_2, \ldots, \beta_K]'$, as the vector of K unknown parameters.

$$V_{in} = \beta_1 x_{in1} + \beta_2 x_{in2} + \beta_3 x_{in3} + \ldots + \beta_K x_{inK}$$
$$V_{jn} = \beta_1 x_{jn1} + \beta_2 x_{jn2} + \beta_3 x_{jn3} + \ldots + \beta_K x_{jnK} \qquad (2.7)$$

Binary Logit Model

In binary logit model, one focuses only on differences in disturbances between one mode and another that is logistically distributed. Binary logit model can be represented in following equation:

$$P_n(i) = \Pr(U_{in} \geq U_{jn}) = \frac{1}{1 + e^{-\mu(V_{in} - V_{jn})}} = \frac{e^{\mu V_{in}}}{e^{\mu V_{in}} + e^{\mu V_{jn}}} \qquad (2.8)$$

CHAPTER III

RESEARCH METHODOLOGY

3.1. INTRODUCTION

In order to accomplish the objectives as listed in the first chapter, a research methodology was developed. In the study, the consideration was first on the selection of research flow charts (conceptual framework) to yield the expected results that would meet the objectives. Then the data collection procedure, the questionnaire, was developed as well as the early stage of questionnaire analyses for collecting the data from field survey were explained in this chapter. Moreover, the survey description was divided into two parts; revealed preference (RP) and stated preference (SP) survey were given in detail as well.

The following subsections in the chapter described the framework and methods used in this study. This included the general development of the survey, experiment procedures, sample size, and modeling methods.

3.2. CONCEPTUAL FRAMEWORK

The conceptual framework was used to describe the overview of the research. Each stage of the work was developed to make a comprehensive scope of work emphasized in this research. The framework, presented in Figure 3.1, was divided into three main stages consisting of survey design and data collection, model formulation and calibration, and application.

The concept of each stage in this framework was summarized as follows:

a. To develop the questionnaire that enable to capture the real life responses to unexpected congestion and hypothetical responses to ATIS scenarios. This included the questionnaire design by applying both revealed preference (RP) and stated preference (SP) data types,

b. To conduct the survey and collect the data, and
c. To model the perception together with the behavior into appropriate and most satisfactory model.

Conceptual framework of the study was explained in the figure below.

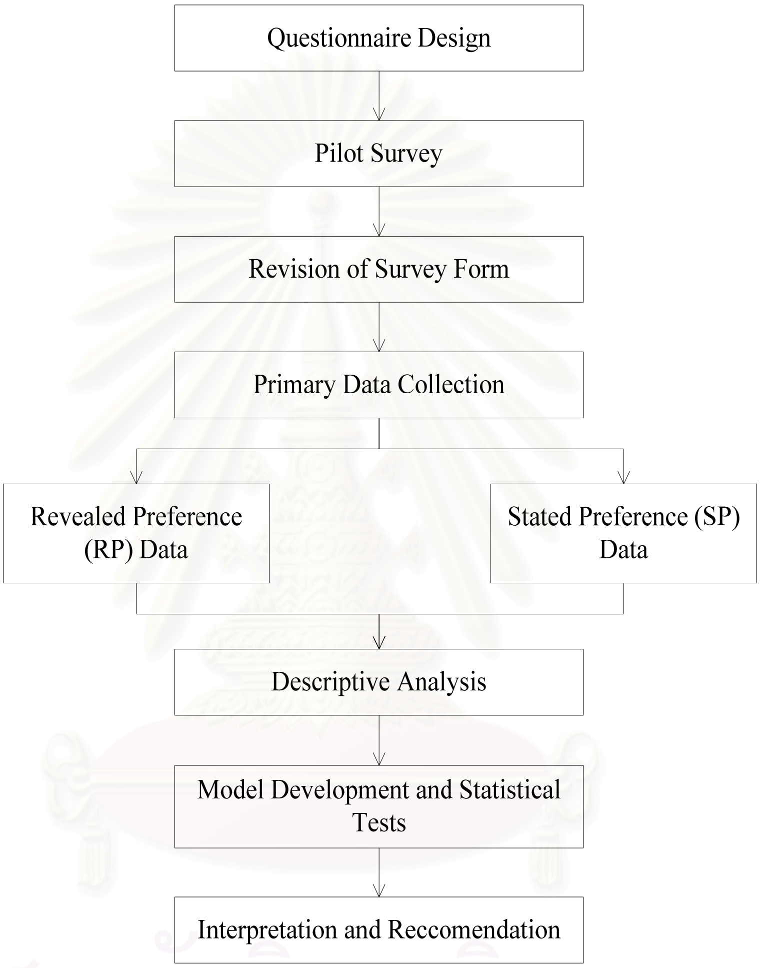


Figure 3.1 Conceptual framework

3.3. DEVELOPMENT OF DRIVERS BEHAVIORAL SURVEYS

3.3.1. Survey Instruments

The paper-based technique was selected to be a survey instrument because it was simple and the survey is targeting drivers in the field. The expected rate of return would be nearly 100% since the method of questionnaire dispersion was semi-interview.

3.3.2. Survey Design

3.3.2.1.General

A key of success in conducting SP survey was the way the researchers (surveyors) presented questions to respondents in order to get realistic responses. It was very important to keep the experiment simple and not overloading respondents to ensure that the answers obtained from the respondents were best to study objectives. It was also recommended that the questions and the way the questions were delivered to the respondents should give respondents some room to have a response outside the set of given choices in order to minimize biases as mentioned before. The value of SP survey depended on the careful application of the guidelines developed. One should carefully consider on how survey was designed to meet the respondents thoughts, so their answers were reliable, not only to satisfy the researcher's desire.

3.3.2.2.Questionnaire Design

The questionnaire was designed to capture the real-world behavior pertaining availability of travel information. The questionnaire was designed in choice and rating scale with 5 points semantic scale for opinion regarding availability of travel information. The study focused only (private car) drivers and did not take into account transit riders since the aim of the study was to perceive drivers' opinion. Neither did we consider participants in car-pool schemes nor who did not drive daily (or did not have the ability to drive). After completing pilot survey, the following categories were selected:

a. **Socioeconomic characteristics,** such as gender, age, and income.
b. **Normal trip characteristics**, such as distance from home to school/work place, flexibility of working hours, which might influence the travel behaviors.
c. **Responses to certain travel information devices**, whether they were ever noticed the information, and the level of understanding to the information. The feedback for the service was also gathered through the survey.

d. **En-route responses to travel time variability and its associated cost**. Given hypothetical scenarios to learn risk-taking behavior of drivers in certain conditions.

The RP part was comprised of five sections (section 1 – 5) and it observed the first three categories. These sections also tried to get the opinion pertaining travel information services, such as the quality of the information, and the preferable information. The SP part was comprised of scenarios involved two travel time probabilities portrayed by two variables; average travel time, and standard deviation travel time.

Average and standard deviation of travel times were chosen since these two were considered to represent the variability in travel time. Three levels were defined for average travel time (varied from 30 to 45 min, 7.5-minute interval per level) and three levels for its standard deviation as well (varied from 4 to 16 min, 6-minute interval per level). The travel time variability was presented to the respondent using a simple way that could be understandable by them.

The respondents were given the mean and standard deviation of travel time presented as journey times in minutes in daily basis for one week. Each variable was varied for both regular and alternate route, then respondents had to decide whether they would stay or change their route based on the information.

Then, in order to perceive the willingness to pay regarding travel time variability, a cost variable was inserted as another variable besides the travel time factors. The expected result from the question could reveal understanding on changing route behavior under tight travel time and cost conditions. Apart from both variables (travel time and cost), other characteristics revealed on RP sections were expected to have a role in the behavior.

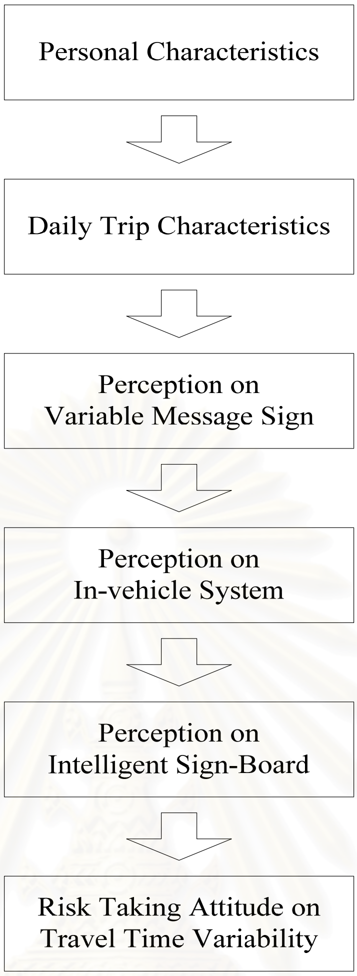


Figure 3.2 Sequences of the questionnaire

The study chose three-level attributes experiments because of the facts that:

- Three levels are more possible to detect such a curvature effect (when there is a curvilinear relation between two factors) than two levels only.
- A qualitative factor may have three levels (e.g. congestion level in high, medium and low).
- It is common to study the effect of a factor on the response at its current setting x_0 and two settings around (higher or lower) x_0.

Therefore, eighty-one possible combinations of average travel time and standard deviation were available for both routes (due to full factorial). In order to reduce the number of scenarios, the study employed fractional factorial and Taguchi's method to come up with nine possible optimum combinations for both routes.

Moreover, the designed scenarios were partitioned into two survey formats and thus each respondent was requested to answer only five sets of scenarios (games).

3.3.3. Data Collection

3.3.3.1.Study Location Overview

Three different places with different characteristics were selected in this study. The study chose Bangkok (Thailand), City of Singapore (Singapore), and (Kuala Lumpur) Malaysia as study cases, concerning that the three countries were located in the same region (South East Asia) but differed in travel information applications and culture.

Singapore

Singapore is known as a small but developed country in South East Asia region with population 4.8 million people as of June 2006 (www.wikipedia.org). It has reached advanced and well-managed transportation system compared to nearby countries that offers comfort and easiness for transit and public transport riders in result. With harmony among its public transportation systems (Mass Rapid Transit, Light Rapid Transit, buses, and taxis), people have almost never had trouble in reaching any places in the country. More than 2.8 million people use the bus network in daily base, while more than 1.3 million people use either the LRT or MRT as part of their daily routine. For the taxi services, approximately 900,000 people use the service daily (www.wikipedia.org). Approximately, the number of road users based on vehicle population in Singapore rose, in mid-year, from 742,156 to 776,571 in 2006 (www.spf.gov.sg).

The transport system has been designed as if one can travel to any places in Singapore; any destination can be reached within an hour or less (regarding its 699.4 km^2 area as well). Major traffic jam rarely occurs in major urban roads, except during peak hours and holiday events. The expressway system (the ring roads as well) facilitates remote areas to be reached easily.

For private car drivers, they are provided with up-dated traffic information such as major roadwork, slow traffic, vehicle breakdowns, accidents, or even closed routes by panels (VMS) which are available on the side of the road. These kinds of information boards could provide useful information to the drivers and assist them to have a safer and pleasant journey. Besides the travel information, the roads are equipped with some surveillance cameras for travel time calculator or for traffic monitoring and enhancing the speed limit regulations.

In general, VMS systems in Singapore are deployed in most expressways and major roads in the city. The content of the message could inform the condition of the traffic ahead, roads closing, or even travel time to particular destinations. An example of the device is illustrated in Figure 3.3 below.

Figure 3.3 VMS in Expressway to Changi Airport, Singapore (*author*)

Furthermore, in some part of the city, congestion charging is applied by Electronic Road Pricing (ERP) that operates during hours of heavy road traffic especially in central areas. ERP is an electronic system based on pay-as-you-use principle and designed as a fair system as motorists are charged when they use the roads during peak hours by deduct the cost from the electronic payment device (using cash card) attached in every vehicle. This device can be used for toll and parking charges as well.

Kuala Lumpur - Malaysia

Kuala Lumpur, the capital city of Malaysia, is also has a well-managed transportation system. Public transport in Kuala Lumpur covers a variety of transport modes such as bus, rail, and taxi. Unlike most other major Asian cities, the utilization rate of public transport is as low as only 16 percent of the population. Commuter trains serve commuters to the city with the main hub in KL Sentral, facilitating as an interchange station for the main lines (www.wikipedia.org).

Electronic payment system is deployed by using Touch-and-Go card for toll and transit payments. Public transport system is as good as in Singapore with lower fares. Moreover, VMS, as one of travel information equipment, has deployed in several points in the city, informs the drivers about the traffic condition ahead. As shown in the picture below, the VMS says about the closing of some major roads due to the “Langkawi Bicycle Tour” event.

Figure 3.4 VMS located in Jalan Ampang, Kuala Lumpur (*author*)

Speaking of traveler information system in Malaysia, with the project named Integrated Transport Information System (ITIS), it is already established and serves commuters Kuala Lumpur for more than one year. This project was initiated by City Hall Kuala Lumpur (CHKL) in response to answer the growing traffic congestion in Kuala Lumpur and its region nearby. The initial deployment is the twin development of its core systems, ATIS and Advanced Traffic Management Systems (ATMS). Thus, ITIS would provide future deployment of other ITS application and services.

These systems cover major roadways encircling Kuala Lumpur as well as its key major roads in and out of the city. With the exception of the KL-Seremban Expressway and the Federal Highway (Route II) Shah Alam – Klang strech, the coverage excludes tolled highways, as these are already equipped with Independent Traffic Control Surveillance Systems. The total length of roads covered by ITIS is about 200 kilometers.

For future long-term deployment, real time data will be obtained through various communication tools such as radio, mobile phones, Multimedia Messaging Services (MMS), Short Messaging Services (SMS), Personal Digital Assistant (PDA), navigators, and others. And also, together with the aim of TMC to be a centre of research excellence, significant data collecting is also expected to be done by various research institutions, private consultancies, and public think tanks (www.itis.com.my).

Bangkok - Thailand

In Bangkok, many intelligent transport systems have been already deployed even though some technologies have not reached the same stage as in Singapore or Kuala Lumpur. (Expressway and Public Transport) Electronic payment has not been popular yet, but remote areas and some places in Bangkok can be reached easily by urban roads or expressways. Traffic jam always occurs on major urban roads, while the expressways sometimes suffer from the same problem. Interactive travel information devices are installed in some busy areas to inform drivers the traffic condition ahead. For public transport, two rail systems (BTS and subway) that started to operate in 1999, serve the city and face the opportunity of expanding the route. Buses, taxis, and tuk-tuks (tri-cycle vehicle) are also available with affordable fares.

Bangkok has several elevated highways, newly rebuilt intersections, and many partially finished road and rail projects but still could not overcome the notorious traffic jam problems in the city. Bangkok could be known as one of the worst traffic cities in the world but it has built an expressway (flyover) or second level road on almost every road in the city center, and there continues to be plans for new expressways. The government has also tried many times to improve the state of the traffic in the city center, which can sometimes take 1 hour just to move 1 kilometer (www.wikipedia.org).

Bangkok drivers were also familiar with Variable Message Sign device, which is deployed in most major roads and critical point through out the city. The picture of VMS device in Bangkok is illustrated by Figure 3.5 below. As informed in the successor chapter, in addition to VMS, Bangkok drivers also familiar with intelligent traffic sign board system as a part of intelligent traffic information system on the city. For public bus riders, the new electronic screen that informed the schedule of buses was ready to be applied.

The idea of intelligent taxi stand and intelligent parking system was thrown together with intelligent traffic signboard idea two years ago and now, the system already applied in certain locations in the city.

Figure 3.5 VMS located in Rama I road, Bangkok (*author*)

3.3.3.2.Data Collection

The sampling framework of this study aims at capturing the pattern the behavior of Bangkok drivers. The primary data obtained were divided into two main parts, (1) the socioeconomic attributes of the drivers, and (2) the characteristics of behaviors in interpreting the information, plus the expected actions in specific conditions.

Then, non-random sampling approach was used in this study. Non-random sampling techniques do offer potential way in reducing the cost of data collection and increasing the precision of parameter estimates. It is arguable that the non-random sampling may be associated with non-representative of the entire population. Care was made to ascertain that the selection of samples was not biased by the interviewers. In practice, the “accidental sampling” was deployed.

Pilot survey was conducted on the beginning of January 2007 with random respondents regarding in their socioeconomic characteristics with a main objective to test whether respondents could understand the content of the questionnaire and to define the ideal numbers for hypothetical scenarios in stated preference part. The initial target was drivers who reside in Bangkok and its surrounding areas, then it was decided that the respondents whose work within Bangkok area and would have a daily trip pattern to his/her school/work place in traffic peak periods. Personalized interview approach was used in the survey in order to assist the respondents especially when the respondent found some difficulties or could not understand the purpose of some questions being asked. From 42 questionnaire dispersed, the response rate was 100%.

After that, the main survey was conducted in three different places with different characteristics of applied technologies.

The questionnaire survey forms were shown in Appendix section.

3.3.4. Determination of Required Sample Size

Sampling of SP surveys was a complex issue, especially when it was related to how many samples, which were sufficient to be studied. Truthfully, numbers of samples were determined based of the scope of the study itself.

By the rule of thumb, it seemed that 30 respondents per segments are sufficient. So far, there was no theoretical basis to encourage this. In fact, the more detailed study that requested higher significance (accuracy such as prediction purpose) required more samples to deal with. As a result, recent studies were often dealing with large numbers of sample. On the other hand, simulation work conducted by Steer Davies Gleave suggested that 75 to 100 samples would be appropriate enough. Then, similar finding were found from Bradley and Koes work in 1990 (Pearmain, et al. 1991).

For this study, the samples used were 82, 124, and 400 respondents for Kuala Lumpur, Singapore, and Bangkok case, respectively. Each respondent was interviewed to five choice situations (games), and this would come up into five times data records that were almost sufficient to calibrate a significant model.

3.3.5. Processing of Data and Information

All the data coming from the questionnaire survey were input to Microsoft Excel in order to give appropriate label of attributes for easier identification before the raw data were imported into statistical software for further analysis. Some assumptions or new variables could possibly be made if necessary as long as it related to the data.

The missing data were reported, and then the data was cleansed in get the final reasonable set of data for statistical analysis and travel (choice) behavioral model development and calibration.

3.4. MODEL DEVELOPMENT

With the presented data from the survey already obtained, a discrete choice set of individual response to traveler information could be performed. A logit model was first presented under IIA assumption. This part of the work provided several developed models. Although the structures of the model were similar, a different set of deterministic and socio economic variables were considered in the model. Statistical measures were given to show which one was the best model amongst all in presenting the drivers behavior into travel information. The type of variables used in the utility function were explained first, followed by how these variables were good in the format of discrete choice modeling.

The statistical model used for analysis was the binary logit model and the calibration was processed by utilizing STATA SE 8.2 software. Attributes were estimated first with categorical coding for all attributes in Microsoft Excel and then with continuous coding for numerical attributes. Then, developed logit models were then used to identify the utility ranking of the drivers' responses to travel information.

3.4.1. Model Assumptions

In order to achieve a representative model, several assumptions in determining the appropriate hypothetical choice values were applied in this study, as follows:

a. The value of hypothetical stated choice scenarios was obtained from the result based on pilot survey in Bangkok. From 42 respondents, the average and standard deviation of travel time was obtained, and this would be the benchmark of the determination of stated choices hypothetical values. Because of these value would be used in the three different cities, adjustments were applied to the results in order to generalized the value which expected to illustrate the same benchmark to the three cities.
b. Besides the travel time values, pilot survey tried to obtain the close-to-reality cost values for stated choice scenarios. Appropriate cost value for each location obtained from the interview process and from the information provided by land transport authorities in each location.

c. Flexibility, travel time, and distance data that used in the model were the result of the combination of morning an afternoon condition.

3.4.2. Statistical Test on Model Development

3.4.2.1.Sign Test on Coefficient Estimates

This basic test ensured whether the expected sign of the coefficient was relevant with the preliminary assumptions or not. Furthermore, the model was verified with similar studies developed in other study places.

3.4.2.2.Significance of Model Parameters (T-statistics) Test

This procedure aimed to test whether any particular elements of the model differ significantly from zero or some other known values. One could use the *t*-distribution to examine whether the confidence limits on that mean included some theoretically predicted value - such as the value predicted on a null hypothesis. Since the difference between the means of samples from two normal distributions was itself distributed normally, the *t*-distribution could be used to examine whether that difference could reasonably be supposed to be zero.

3.4.2.3.Goodness-of-fit Test

Goodness- of-fit test measured how well a statistical model fit an asset of observations. It was typically summarize the divergence between observed values and the expected value under the model.

3.4.2.4.Likelihood Ratio Test

Log Likelihood showed how likely that the observed values of the dependent variables might be predicted from the observed values of independent variables, the higher the value the better. It was a value of the parameters observed sample was most likely to have occurred. The estimators were consistent, asymptotically normal, and efficient.

To evaluate the significance of the estimated parameter, one can conduct likelihood ratio test that was shown in the equation below,

$$-2\left[LL(\beta_R) - LL(\beta_U)\right] \tag{3.10}$$

Where $LL(\beta_R)$ is the log likelihood at convergence of the “restricted” model and $LL(\beta_U)$ was the log-likelihood at convergence of the “unrestricted” model. Overall model fit was the ρ^2 statistic:

$$\rho^2 = 1 - \frac{LL(\beta)}{LL(0)} \tag{3.11}$$

Where *LL(β)* was the log-likelihood at convergence with parameter vector β and *LL(0)* was the initial log-likelihood (with all of the parameters set to zero).

$$corrected\ \rho^2 = 1 - \frac{LL(\beta) - K}{LL(0)} \tag{3.12}$$

Where *K* is the degree of freedom from parameters involved in the model.

3.4.2.5.Model Structure Test

To detect the violation in the model**,** the direct comparison between the estimation result and a generalized model contains the basic assumptions that are being tested.

3.4.3. Model Validation

Refer to Ben-Akiva and Lerman (1985) model validation can be run by using the data that used in model estimation or using other data that was not used during the estimation process as a validation sample. In this case, for the validation process we used both of the data used in the estimation and another set of data. Since the model were estimated for three different cities and each city has its own model, then cross validation among the cities could be carried out.

CHAPTER IV

SURVEY RESULTS

4.1. INTRODUCTION

This chapter presents the descriptive analysis of the data in detail. The correlation of some variables will be shown through some graphs and tables as well as the description of the data. From the data collected from cities in three countries, we can see the differences among the three of them and later we can see how these variables would explain the diverting decision using behavioral models.

For the main survey, a total 200 questionnaires survey conducted in Kuala Lumpur and Singapore during February 2007 and achieved response rate of 40% in Kuala Lumpur and 60% in Singapore. In mid of March the last survey was done in Bangkok with total respondents of 400. Further analysis on descriptive analysis and model development using binary choice technique would be conducted based on these data. Descriptive analysis expected to illustrate the real condition behavior of drivers while model estimation aims to predict the travel behavior also as a tool in comparing one location to another.

4.2. SOCIO-ECONOMIC DISTRIBUTIONS

Table 4.1 Sample socioeconomic characteristics

Attribute	Range	Bangkok Survey Sample (%)	Kuala Lumpur Survey Sample (%)	Singapore Survey Sample (%)
Gender	Male	52.3	65.9	49.19
	Female	47.8	34.1	50.81
Age Group	Under 25	15.0	39.0	23.39
	25 - 35	47.3	36.6	45.16
	35 - 45	26.5	8.5	17.74
	45 - 50	9.3	9.8	8.06
	Over 50	2.0	6.1	5.65
Income		9.00 (< 10,000 THB)	32.9 (< 1,000 RM)	22.6 (< 1,000 SGD)
		20.5 (10,001 - 20,000 THB)	35.4 (1,001 - 2,500 RM)	36.3 (1,001 - 2,000 SGD)
		26.75 (20,001 - 30,000 THB)	11.0 (2,501 - 4,000 RM)	33.9 (2,001 - 5,000 SGD)
		28.5 (20,001 - 30,000 THB)	8.5 (4,001 - 5,000 RM)	6.5 (5,001 - 10,000 SGD)
		15.25 (> 30,000 THB)	12.2 (> 5,000 RM)	0.8 (> 10,000 SGD)

Table 4.1 shows the socioeconomic characteristics of the samples, and this table mainly describes the data proportion from the survey process. From three cities, the gender proportion of respondents was not much different between male and female drivers, except for Kuala Lumpur. Young drivers were dominating the number of total respondent compared the older one (> 45 years old). Moreover, the survey result indicated that, in majority, people with middle-class income tend to drive their own car compared to high-class income drivers. In this study, people with low income was categorized in the first class of income, middle class income defined as people with income categorized in the second to third class of income, then the rest classified as high-income classes.

Since the data was gathered by accidental sampling method, these sets of samples as seen from the socio-economic characteristics might not represent similar characteristics with driver population in each city. Nonetheless, to our study context, these characteristics were observed during the determination of travelers' behaviors. The data suggested that the similarity of travelers' behavior across the socio-economic groups might be examined before the aggregate comparison could be drawn among three cities.

4.3. TRIP CHARACTERISTICS

4.3.1. General

The questionnaire was designed to obtain the travel characteristics from our study locations, and it was expected to be able to capture some unique characteristics owned by particular study areas. Suppose, these characteristics could indicate and explain the uniqueness travel behavior of the drivers from one city compare to the others.

On Table 4.2 below, we can see the detailed trip characteristics of the respondents. The trip concerned in the survey was specified for daily work and school trip base only. The attributes of the underlying trip covered the flexibility of the trip, trip distance and travel time, familiarity of alternate route, and presence of alternate route.

Table 4.2 Trip characteristics

Characteristics	Range	Bangkok Survey Sample (%)	Kuala Lumpur Survey Sample (%)	Singapore Survey Sample (%)
Morning Flexibility	Yes	47.50	54.88	20.16
	No	52.50	45.12	79.84
Afternoon Flexibility	Yes	52.50	69.51	33.87
	No	47.50	30.49	66.13
Alternate Route Availability	Yes	66.50	57.32	38.71
	No	33.50	42.80	61.29
Familiarity on Alternate Route	Very Strange	1.08	7.32	0.81
	Strange	5.76	10.98	4.84
	Average	42.81	21.95	22.58
	Familiar	43.17	30.49	29.03
	Very Familiar	7.19	29.27	42.74
Frequency Using Alternate Route in the Morning	1-2 times a week	3.00	30.49	12.90
	1 -2 times a month	28.00	40.24	28.23
	Less than 5 times per year	38.50	21.95	33.06
	Never	30.50	7.32	25.81
Frequency Using Alternate Route in the Afternoon	1-2 times a week	3.75	36.59	13.71
	1 -2 times a month	30.50	37.80	26.61
	Less than 5 times per year	35.25	23.17	36.29
	Never	30.50	2.44	23.39
Using the Same Alternate Route	Yes	59.35	67.07	52.46
	No	40.65	32.93	47.54

As seen on the table, Kuala Lumpur drivers had the most flexible working hour, and Singapore drivers had the least. Emphasized in Figure 4.1 below, the distribution of start and end working hour for Kuala Lumpur was more distributed through the time compared to the schedule of Bangkok or Singapore drivers. This situation implicate that for those who has odd work schedule, they might endure different situation of traffic congestion and delay. This condition could result into different perception or different travel behavior.

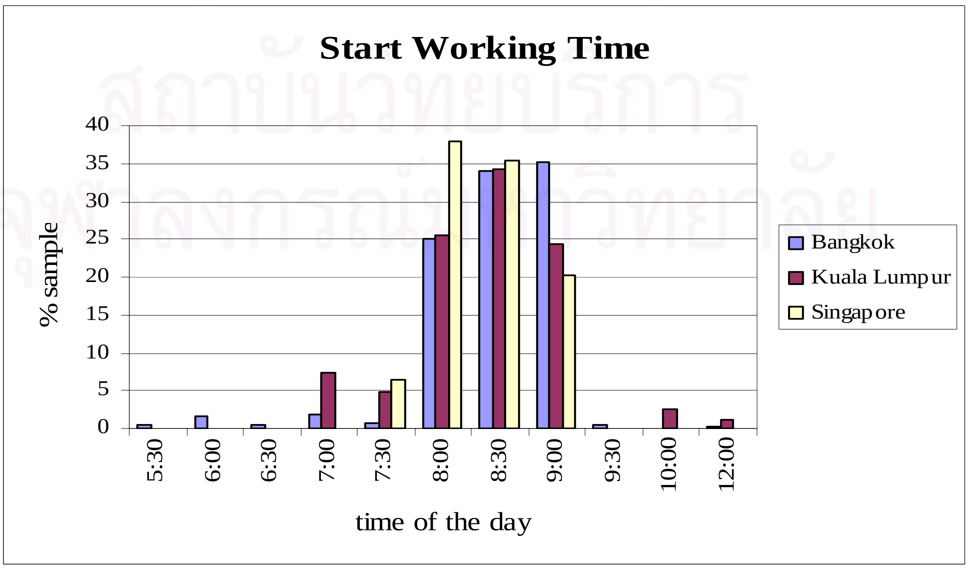


Figure 4.1 Distribution of start working hour

As presented in Figure 4.1 and Figure 4.2, although different city had different time distribution, the trend of start and end working hour distribution for all the cities concentrated on 8 – 9 AM and 16 – 17.30 PM. These periods could indicate the peak hour period of traffic congestion for both morning and afternoon in three underlying cities as well. If we assume the average travel time is about 45 minutes, then for instance Bangkok would suffer from traffic congestion started from 7 until 9 AM for morning trips. Furthermore, by compared the time distribution among the cities, the flexi-time schedule in Kuala Lumpur case could be one of solutions to reduce the severity of traffic congestion.

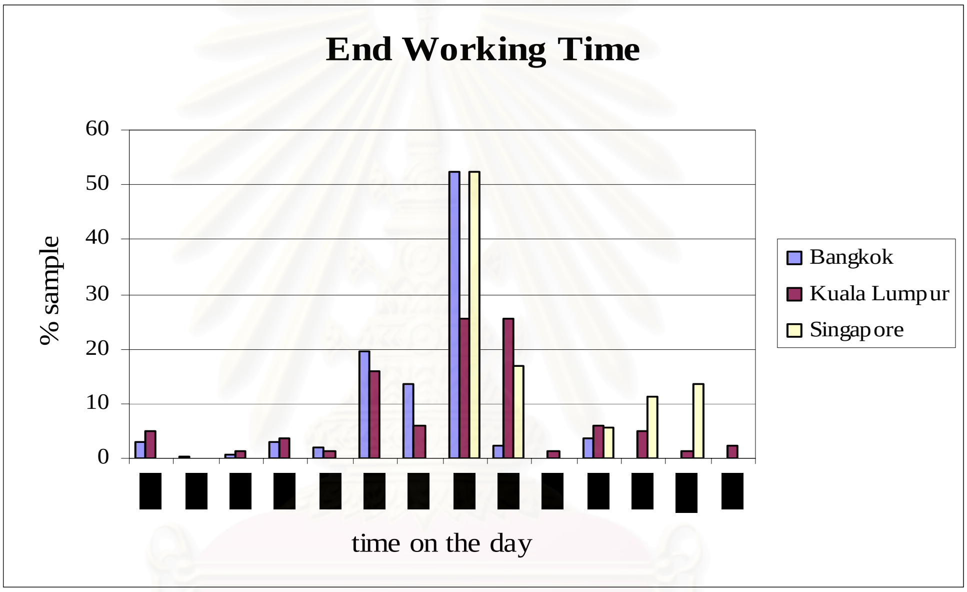


Figure 4.2 Distribution of end working hour

Another fact gathered from the survey beside the schedule distribution was the flexibility of the schedule itself. These data expected to be capable in explain the distinction of travel behavior between morning and afternoon trip. This result showed that drivers tend to be more fixed on their schedule in the morning than in the afternoon. As we can see in Figure 4.3, afternoon schedule was more flexible than the morning ones. This could indicate that drivers were more open to uncertainty and unexpected travel condition in the afternoon. Then, the possibility for drivers to change their route for reasons as avoiding congestion or going to second places were more open for afternoon trips.

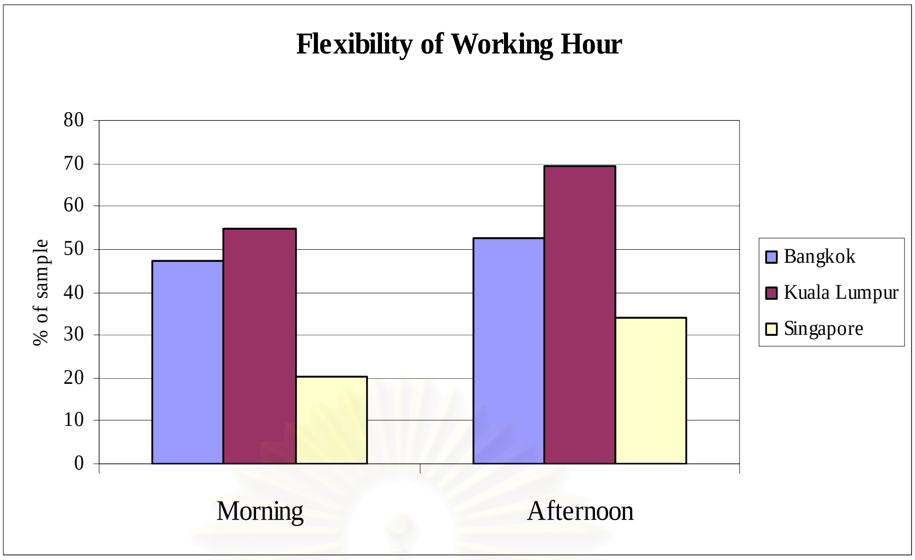


Figure 4.3 Flexibility of working hour

Speak about the change route behavior, the decision to detour was determined by some factors as the availability of alternate route and the familiarity of the route itself. Based on the data, if we look back to Table 4.2, only about 39 percent of Singapore drivers confessed that they had alternate route while the other 61 percent just rely on their main route. In comparison, the two groups were evenly distributed in Kuala Lumpur case, and even in Bangkok, more than 66 percent of respondents said that they do have alternate route.

On the contrary, the percentages of Singaporean who admit that he/she was familiar of their alternate route exceeded the numbers of respondents who confessed that they had other possible routes. This situation implies, even Singapore drivers had their own alternate route, they rather preferred staying on the main route to diverting to alternate route.

Moreover, most of drivers in Bangkok admitted that they possessed alternate route, but the frequency of using any other route beside their primary was relatively low. Only about 31 percent of them said that they used it regularly (1-2 times or more per month), while the rest admitted that they used it if it necessary or even never. The same pattern was shown by Singaporean while most Malaysian declared that they used it as a part of regular activities. If we look in detail to the record, we can conclude that for the three cities, they were likely to keep on their major route especially on the morning trip. However, they opened a possibility to change their route if something happened on the major route during evening trip. We can conclude this by comparing the percentage of flexibility, and frequency of using alternate route in the morning and in the afternoon.

From this finding, we can reckon that the three cities citizens differ in their changing route behavior. Most of Bangkok and Singapore drivers had the same working hour scheduled so this might be the main reason of traffic congestion especially on peak hour period. However, Bangkok drivers seemed to be either more tolerate or did not have any other choices then they chose to stay on their route. On the other hand, Singapore drivers showed the same behavior but with different reason and different situation. In Bangkok, when the traffic was so severe and in case, we were trapped in traffic jam; we would have nothing to do but to bear the condition. Similarly, in Singapore, the congestion was always occurred on peak-hour periods but the condition was not as terrible as Bangkok. Drivers might insist to stay in the route because it far more efficient to stay rather than change the route. Different from the two cities mentioned earlier; drivers in Kuala Lumpur seemed to have a number of alternative routes beside their usual.

The next two graphs illustrate information about the traffic condition and driver's behavior for the three study locations.

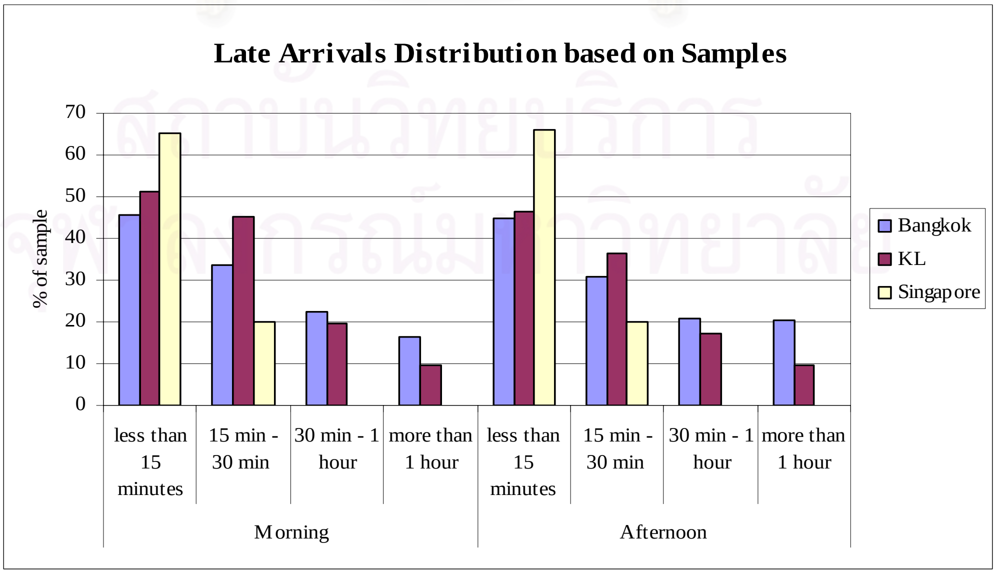


Figure 4.4 Distribution of late arrivals based on number of drivers

Earlier in the survey, we asked about how frequent they experienced specific duration of late arrival from their expected travel time in morning and afternoon trip in a month period. Figure 4.4 illustrates the distribution of delays that portrayed by late arrivals that occurred to the drivers.

From the survey, more than 50% of the total interviewed drivers experienced delay up to 15 minutes for both morning and afternoon trip. As clearly seen, the number of drivers was decreased as the delay increased. Somehow, for delay reaching to or more than one hour, there were still about 10 – 15 percents of the total respondents that still experienced this very long delay.

To make this graph more understandable, we can have a look to Figure 4.5 which presents the late arrivals experienced in the average number of days/month. From this graph, we can see that in average Bangkok drivers experienced up to 15 minutes about 7 days/month and still experienced more to one-hour delay in about 3 days/month, which proved that Bangkok drivers engaged with a lot of variability on their travel time compared to the others.

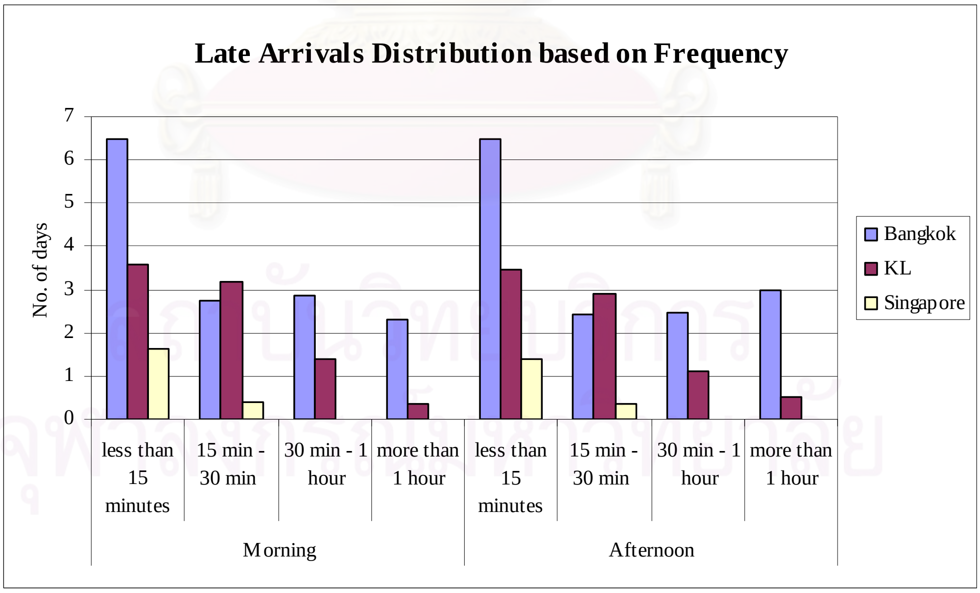


Figure 4.5 Distribution of late arrivals based on its frequency

To conclude the two graphs above, we can say that in Bangkok drivers deal with a lot of variability and unexpected condition on their trip, indicated by the high numbers of late arrivals in both graphs. We can also tell that Singapore drivers were likely to be punctual in their trip compared to drivers in Bangkok and Kuala Lumpur. This can be seen by the number of days that they had late arrivals for both morning and afternoon were relatively low. In average, Singapore drivers experienced late arrival from their usual arrival time by up to 15 minutes about 2 days in a month with variation of occurrence around 2 until 3 days. For late arrivals up to 30 minutes, it occurred rarely or almost never.

4.3.2. Sensitivity in Additional Delay

Table 4.3 Distribution of travel time based on distance

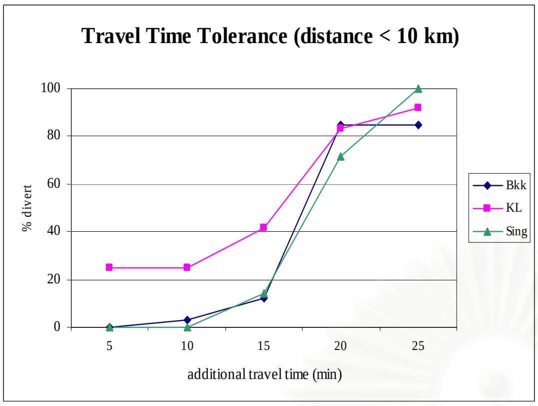
	Bangkok			Kuala Lumpur			Singapore		
	travel time (min)	Morning (% of sample)	Afternoon (% of sample)	travel time (min)	Morning (% of sample)	Afternoon (% of sample)	travel time (min)	Morning (% of sample)	Afternoon (% of sample)
distance < 10 km	10	4.05	5	5	13.79	10.34	5	5	0
	15	4.05	5	10	6.90	10.34	10	72.5	22.5
	20	6.76	6.67	15	34.48	31.03	15	20	55
	30	39.19	15	20	13.79	13.79	20	2.5	20
	35	1.35	0	25	3.45	6.90	25	0	2.5
	40	8.11	10	30	10.34	6.90			
	45	22.97	20	35	3.45	6.90			
	50	5.41	5.00	40	3.45	6.90			
	60	8.11	20	50	3.45	6.9			
	70	0	1.67	60	6.9	0			
	75	0	5						
	80	0	1.67						
	90	0	1.67						
	105	0	3.33						
No of sample		74	60		29	29		12	40
distance 10 ≤ n ≤ 30 km	12	0.32	0.31	15	2.38	2.44	20	42.67	42.67
	15	0.64	0.62	20	11.9	12.2	25	54.67	54.67
	20	4.18	3.69	30	16.67	17.07	30	2.67	2.67
	25	1.29	0.92	35	4.76	4.88			
	30	18.97	15.69	40	11.9	12.2			
	35	0.96	0.31	45	11.9	12.2			
	40	9.65	9.85	60	21.43	21.95			
	45	10.29	10.77	80	4.76	2.44			
	50	10.61	9.23	90	14.29	14.63			
	55	0.32	1.23						
	60	29.58	26.77						
	70	1.29	1.54						
	75	3.22	3.38						
	80	1.61	2.15						
	90	4.18	8.31						
	105	0.64	2.77						
	120	2.25	2.46						
No of sample		311	325		42	41		40	75
distance > 30 km	60	40	40.00	45	9.09	25	40	22.22	0
	70	13.33	13.33	50	0	8.33	45	77.78	22.22
	75	13.33	6.67	60	36.36	25	60	0	77.78
	80	0	6.67	75	27.27	8.33			
	90	26.67	26.67	80	9.09	8.33			
	120	6.67	6.67	90	9.09	16.67			
				105	9.09	8.33			
No of sample		15	15		11	12		75	9

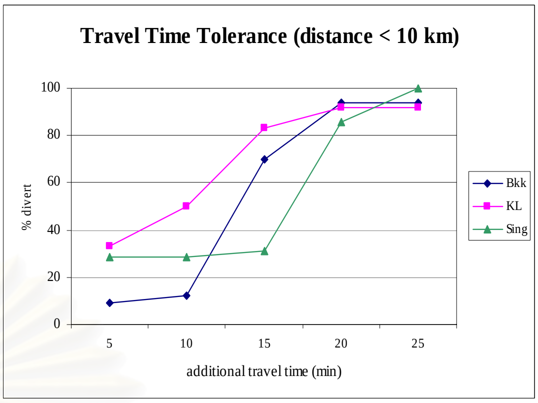
By looking into Table 4.3, we can acquire the brief traffic condition of the three cities based on the travel time associated to its distance. All the data were assumed as daily basis travel from home to work and vice versa. In Bangkok, during morning trip most people would have to bear 30 – 60 minutes to travel on 10 km or less distance. For longer distance from 10 to 30 km, obviously people needed to travel around 60 minutes while for trip distance more than 30 km, they needed to travel within one and a-half hour. This travel pattern was more or less the same for afternoon trip unless, the distributions of travel time through out the distance were more constant.

For Kuala Lumpur case, most of short trip distance reported to consumed time around 15 minutes for both morning and afternoon trip. Then, for longer distance up to 30 km, the average travel time was 60 minutes while it could be up to 1 and a half hour travel time for distance beyond 30 km for afternoon trip. On contrary, travel within the city for Singapore seemed more comfortable than the other cities. As an instance, about 72 percent of drivers said that short distance trips only consumed 10 minutes travel time in the morning, while it took 5 minutes longer in the afternoon. For distance up to 30 km, it took around 25 minutes travel time while for longer distance; it would spend around 45 until 1 hour the longest.

This observable fact might origin from different condition of transportation infrastructure yet the habit of the three cities. While Bangkok and Kuala Lumpur more or less having the same condition and driver habits, traffic management in Singapore seemed to be more advanced.

Next, we will discuss about the threshold of travel time tolerance among the three underlying cities. The respondents were asked to indicate the level of delay that they would tolerate and beyond which they would determine to change from their main route. The discussion was split into three part based on the distance that corresponded to its travel time to avoid biases between commuter and non-commuter behavior. From five statements of detour actions, respondents were generally categorized as divert to specific alternate route if their response was “can not say” until “definitely detour” while the rest classified as stay. In Peeta et al. work in 2000, the assumption of categorizing the statements into two choices was different with our work here. Peeta categorized “can not say” as stay on the main route as they assumed that this choice would mislead the results, especially in modeling process.





(Figure 4.6.a) **(Figure 4.6.b)**

Figure 4.6.a and **4.6.b** Travel time tolerances for distance less than 10 km

As we see on Figure 4.6 above, these graphs illustrate the travel time tolerance for those who had alternate route and traveled with distance less than 10 km from home to work. The left side is the graph assumed “can not say” as stay choice while the right side graph assumed that “can not say” was more likely to detour. It is clear to see that for our assumption, the result was more logical in term of the number of drivers who divert after experienced 15 – 20 minutes delay. Moreover, the assumption was based on the data proportion, and it seemed to be more rational for determining the same assumption for the next model estimation process.

Figure 4.6 shows that Kuala Lumpur drivers tend to be more sensitive to additional travel time, as we see that the number of drivers who claimed that they would divert was higher that the other two cities for additional 5 to 10 minutes to their usual travel time. However, as the additional time increased to 15 minutes and more, the number of diverted drivers was not as significant as before. Bangkok drivers showed significant number of diverting drivers after experienced 15 minutes of delay. As we can see on the graph, about 70 percent of drivers decided to detour after experiencing 15 minutes delay. After 20 minutes of delay, the numbers of additional diverting drivers were not as significant as before. These results mean that the time extension up from 15 minutes had not significantly made drivers to divert since they were realized that they were late already, then it did not matter whether or not change the route. Then, we can see that even they experienced delay for 20 minutes or more, there were still a number of drivers insisted to stay on their route. This may indicate that these drivers were unfamiliar on the alternate route then whatever it takes, they would like to stay than divert to unfamiliar route.

On the contrary, Singapore drivers yielded different and unique behavior than Kuala Lumpur and Bangkok drivers. As we see on the graph, although the number of drivers that aware of delay of 5 until 10 minutes time were higher than Bangkok case, the trend of incremental number of drivers who divert was indifferent until drivers experienced delay for 15 minutes, then it increased significantly about 80 percent of total number of drivers. This indicates that for short distance trips, Singapore drivers were more likely to be tolerant than other drivers did.

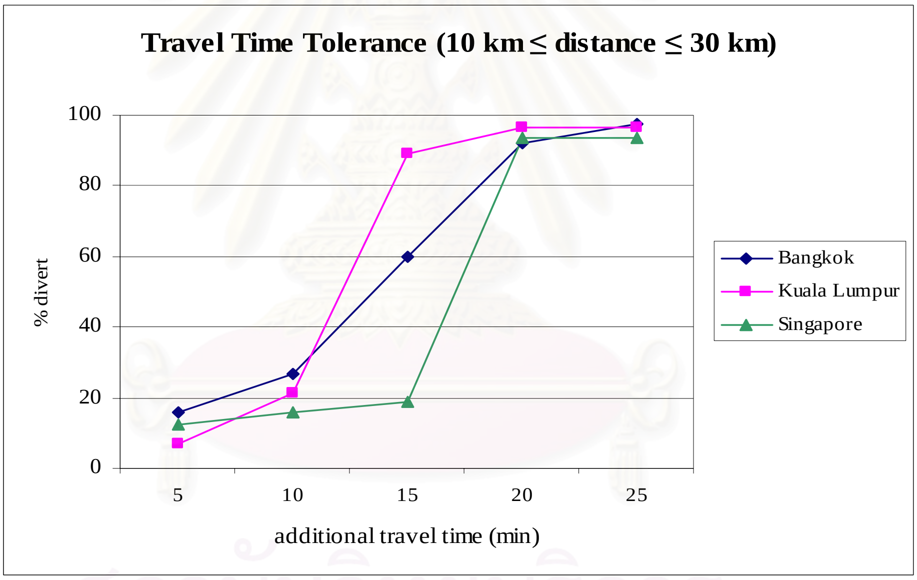


Figure 4.7 Travel time tolerances for distance 10 to 30 km

For medium-distance (10 to 30 km), the drivers yielded a slightly different behavior than previous graph. The critical delay for the three cities is about 10 to 15 minutes longer from normal travel time, unless for Singapore drivers who altered from critical threshold 15 to 20 minutes delay. Kuala Lumpur drivers seemed to be less sensitive compared to the shorter distance, so did Bangkok drivers in terms of incremental diverting drivers. Singapore drivers showed more logic behavior, but still there were a number of drivers who did not choose to divert after 20 minutes or more delay.

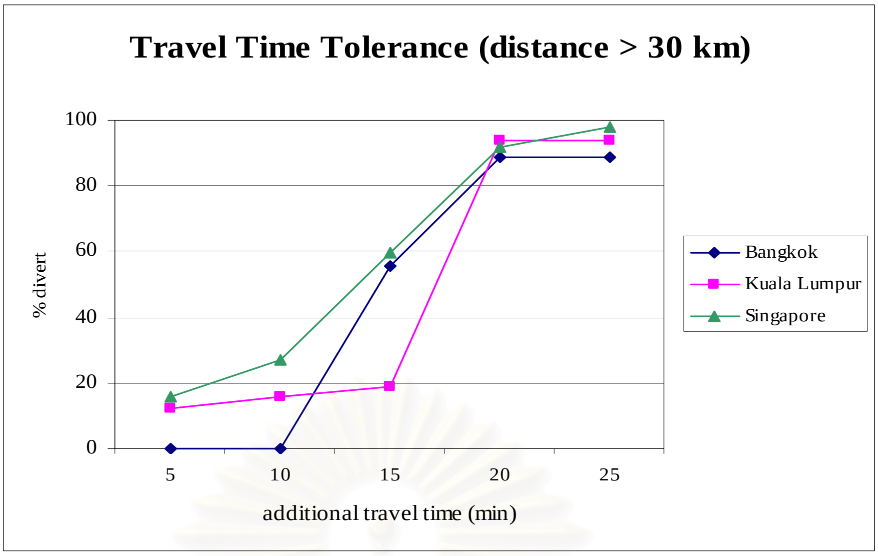


Figure 4.8 Travel time tolerances for distance more than 30 km

Figure 4.8 above explains about the behavior of non-commuter drivers (drivers with trip distance more than 30 km) in the three cities. Slightly different with the previous graphs, for non-commuter drivers, all the drivers in three cities were showed different behavior compared to the two successor graphs.

Non-commuter drivers in Singapore tend to be more sensitive to additional travel time to commuter drivers. For additional 10 to 15 minutes delay, the slope of the graph that indicated the number of drivers who divert was sharper than previous graphs. For Kuala Lumpur case, the number of diverting drivers increased sharply when they experiencing more than 15 minutes travel time. All Bangkok drivers decided to stay on their route even they experienced additional 5 to 10 minutes on their travel time. After 15 minutes delay, about 55 percent of drivers decided to divert.

This result showed that Bangkok non-commuter drivers tend to be more tolerant than commuter drivers were. This phenomenon shown by the critical delay for diverting were around 10 to 15 minutes from normal travel time. For Bangkok case, even the significant percentage of diverting drivers was generally the same with previous cases. Unless, for additional 15 minutes travel time, the drivers who claimed that he/she would divert from their usual route just about 40 percent of total sample compared to 70 percent drivers in previous cases. The same situation occurred to Kuala Lumpur drivers. The significant increment of diverting drivers altered from 10 to 15 minutes delay into 15 to 20 minutes of delay. Obviously, about 70 percent drivers would detour when they experienced 15 until 20 minutes delay. It differed from earlier cases while about 60 percent of drivers chose to change their route when experienced 10 to 15 minutes of delay.

From the three graphs, we can achieve a conclusion that for the three cities, the behavior of commuter drivers was different with non-commuter drivers. Non-commuter drivers tend to be more tolerant than commuter drivers were when experienced delay in their travel time. This situation could be a result as compared to their travel time (which is about 40 into 120 minutes in total), the 5 until 10 minutes additional travel time seemed to be nothing for them. For Singapore drivers, they were more sensitive to delay in order to avoid severe traffic congestion on the next route. If they were late for even 5 minutes, they had to bear longer delay caused by the traffic congestion.

4.3.3. Reasons for Changing Route Behavior

Not only interpreting the diverting behavior due to general reasons such as delay in travel time, we also asked the respondents about the specific reasons behind their decision in changing route, as shown by Figure 4.9 below.

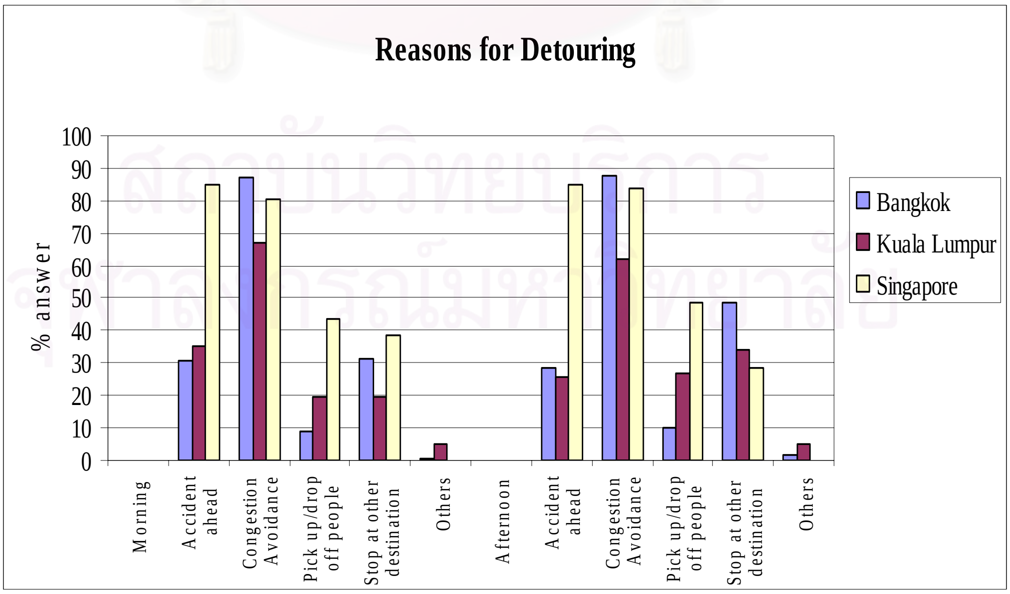


Figure 4.9 Reasons behind changing route behavior

Most of respondents answered avoidance of accident and congestion, which is related to the traffic condition as their best answer. For other options related to personal matters such as pick/drop off people and stop at other destinations, it result not so significant numbers, but it seems that people answered these options differently for morning and afternoon trips. Most of drivers consider more for personal reasons in diverting their route during afternoon trip instead of the morning trip. This might occur because afternoon trip not as tight as morning trip, hence they had the chance to slot in their personal matters on it.

4.3.4. Methods in Learning Traffic Condition

As we see on the previous discussion, traffic condition was the primary consideration for drivers to determine whether change their route or not. We asked the respondents what were their primary methods in knowing about traffic condition. Most of them answered that both of personal observation and availability of traffic information were the best method for them for learning the traffic condition. Some drivers answered other sources such as by priori knowledge and by information told by acquaintances. The exact illustration can be seen in Figure 4.10 below. We can learn more about the traffic information characteristics on the next section.

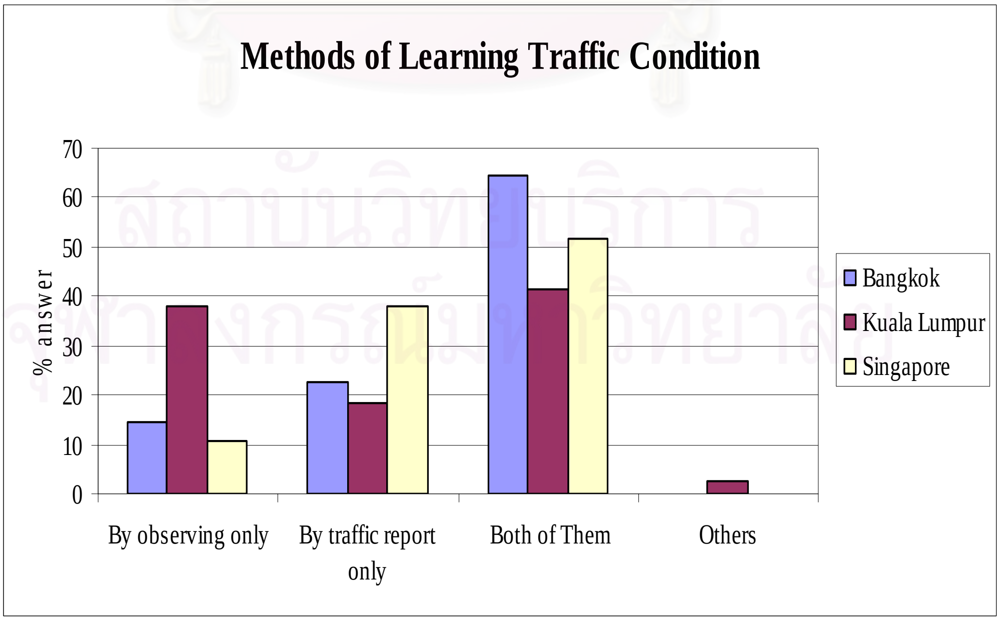


Figure 4.10 Methods in learning traffic condition

4.4. TRAFFIC INFORMATION CHARACTHERISTICS

4.4.1. Sources of Traffic Information

In the survey, we also asked the respondents about their knowledge about traffic information and their behavior in getting them. Based on the survey result, in majority traffic information relayed by radio broadcast had been the primary source of traffic information for drivers in Bangkok and Kuala Lumpur while Singapore drivers rely more on traffic information broadcast on television or getting information from newspaper. Personal knowledge also stood out as one of important traffic information sources. For ATIS devices, VMS and Intelligent Sign-Board were being traffic information sources for come drivers while the other services such as internet, in-vehicle device, or phone call service are less popular due to several reasons.

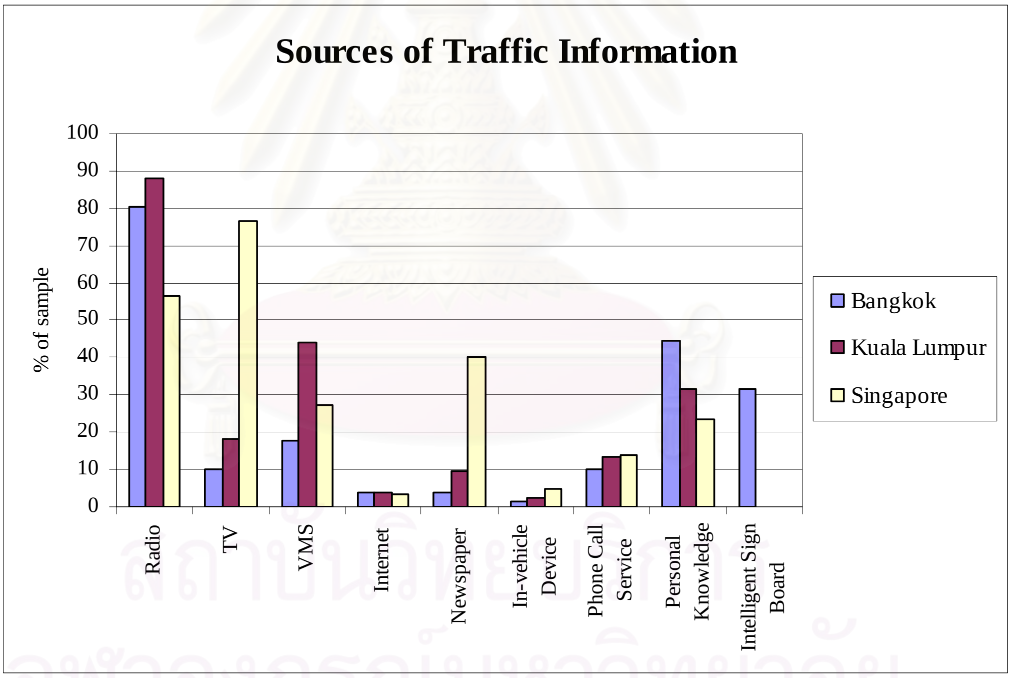


Figure 4.11 Sources of traffic information

One of the interesting things is the number of drivers who said that VMS being one of their traffic information sources varied for the three cities. This occurrence might happen due to the accuracy rate of the information given, as we will have further discussion about it in the next sub-section.

4.4.2. VMS Characteristics

Not only the general behavior in changing route, the questionnaire also tried to capture the specific changing route behavior related to traffic information availability. We asked the feedback and perceptions from drivers towards the quality of ATIS devices in traffic information, including Variable Message Service (VMS), In-vehicle Device (IVD) and Intelligent Sign-Board (ISB).

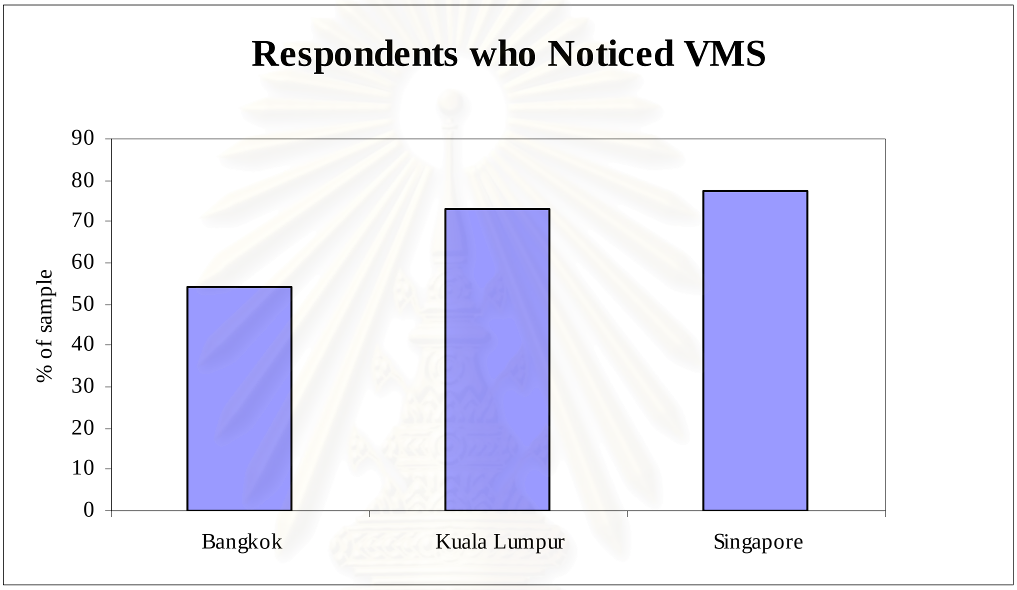


Figure 4.11 Driver's responses to VMS

The graph above shows the driver's awareness to VMS devices on the three countries. For the three cities, the initial response to the device was good. For Singapore and Kuala Lumpur, the driver's awareness of ATIS devices was quite high shown by the percentage of total drivers who admit that they were notice about VMS application in the city was beyond 70 percent of total sample. This can be understand-able since in both cities VMS devices already installed in most vital spots inside the city.

Slightly different, as shown in the graph Bangkok drivers were moderately split into two groups between drivers who did notice VMS messages during their daily trip and those who did not. This situation could be a result of various reasons. First, those who admit that they were unable to notice any VMS device were non-commuter who resides outside the city. Second, the deployment of the device have not reached all the crucial spots within the city, and the last prejudgment is, in fact the drivers noticed the existence of the device but since the information are non-beneficial then they practically chose ignoring it.

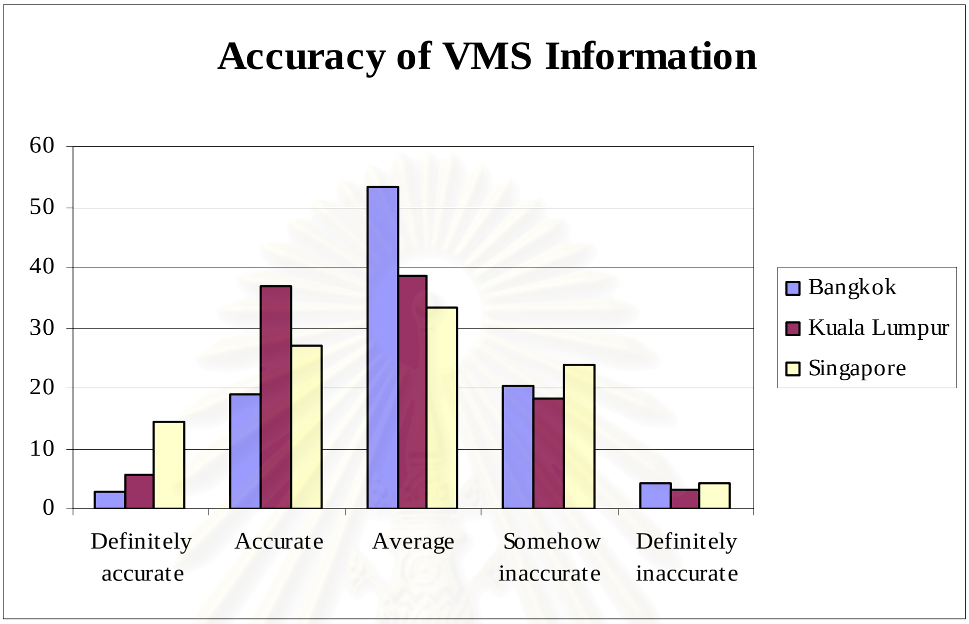


Figure 4.13 Accuracy of VMS information

Figure 4.13 shows the perception of drivers from the three cities towards the content of VMS information. From the graph, it is easy to capture that the content of VMS information were rated as average in its accuracy. This means that we could not rely 100 percent on the given information.

One remarkable thing is, Bangkok drivers tend to be pessimistic on VMS information than the other two cities. It can be seen that the number of drivers who said that the accuracy of VMS information was good was lower than the other cities.

4.4.3. In-Vehicle Device Characteristics

In vehicle device is one of newest ATIS system introduced to the market. Now, this system are relative uncommon but has enormous users' expectation regarding its offered system. One thing that makes this system is interesting than other services that, it offers privatized, personal, and detailed traffic information to drivers. This is different with the characteristics of VMS information, which gives general information and open for all drivers who travel in the same direction (since the information is free). Moreover, by using this device drivers can select which type of information that they need most. In general, the device expected to has more utilization level for drivers, associated with its prices.

Table.4.4 Type of in-vehicle device information with its rate of usefulness

	Bangkok					Kuala Lumpur					Singapore				
	Very Useless	*Quite Useless*	*Can Not Say*	*Quite Useful*	*Very Useful*	*Very Useless*	*Quite Useless*	*Can Not Say*	*Quite Useful*	*Very Useful*	*Very Useless*	*Quite Useless*	*Can Not Say*	*Quite Useful*	*Very Useful*
accident info	0.3	7	33.5	46.8	12.5	0	1.22	9.76	47.56	41.46	0	1.61	32.26	33.87	32.26
travel time	0.3	5	39.5	43.8	11.5	1.22	2.44	26.83	47.56	21.95	1.61	0	30.65	55.65	12.1
congestion	0	2.25	24.5	52.5	20.8	1.22	2.44	14.63	48.78	32.93	0	1.61	33.06	43.55	21.77
route guidance	0	3	34.8	47.3	15	0	2.44	14.63	50	32.93	0	20.16	43.55	22.58	13.71
alternative route	0.3	4.75	33.3	45.3	16.5	0	2.44	19.51	52.44	25.61	0	8.87	59.68	26.61	4.84
parking availability	1	12.8	44	36.3	6	3.66	7.32	26.83	41.46	20.73	2.42	39.52	45.97	7.26	4.84
interesting places	3.5	32.8	39.3	20.8	3.75	2.44	21.95	31.71	30.49	13.41	12.9	23.39	44.35	15.32	4.03
potential alt. destination	0.5	25.3	37.8	31.5	5	0	3.66	37.8	45.12	13.41	0	45.16	41.13	8.06	5.65
weather report	6.8	34	37.3	20.3	1.75	1.22	23.17	35.37	25.61	14.63	11.29	2.42	35.48	46.77	4.03

Based on the extent benefit that expected from the device; this study tried to acquire the type of information that suggested to be provided by the device by asking the respondents' opinions. By looking to Table 4.4, we can see the trend of drivers' opinion from the three study locations. Most of drivers in Bangkok and Singapore tend to answer 'quite useful' as their highest rate while Malaysian was more optimistic towards the device.

Information regarding congestion level still favored by Bangkok drivers since the city suffers from severe traffic congestion problem. Other prosperous information would be travel time, route guidance, and alternative route availability. For drivers in Kuala Lumpur, accident info does matter than other kind of information. Then (again) congestion level and route guidance placed as the second place of the most important information to be put on the device.

In opposition, Singapore drivers thought that travel time is the most important information for them; this can be proved as many variable message boards in the city inform drivers about travel time from one place to another. Moreover, accident information and weather report are the other information, which they thought might be essential to be provided by the device.

This result mainly illustrated the first impression of drivers to the device since this technology is still new and not so many drivers using and familiar to this technology. The answers were purely prior expectation to the device, so then if they would like to purchase this device, they sure enough the device would gives the right information for them.

4.4.4. Intelligent Sign-Board Characteristics

In Bangkok, one of the newest ATIS that already deployed in some spots within the city is Intelligent Sign-Board, which shows the real time congestion level in some major roads to drivers. This technology deployed for about two or three years already and gained numbers of opinion regarding its performance. We would like compare the expectation and opinion after the system was established.

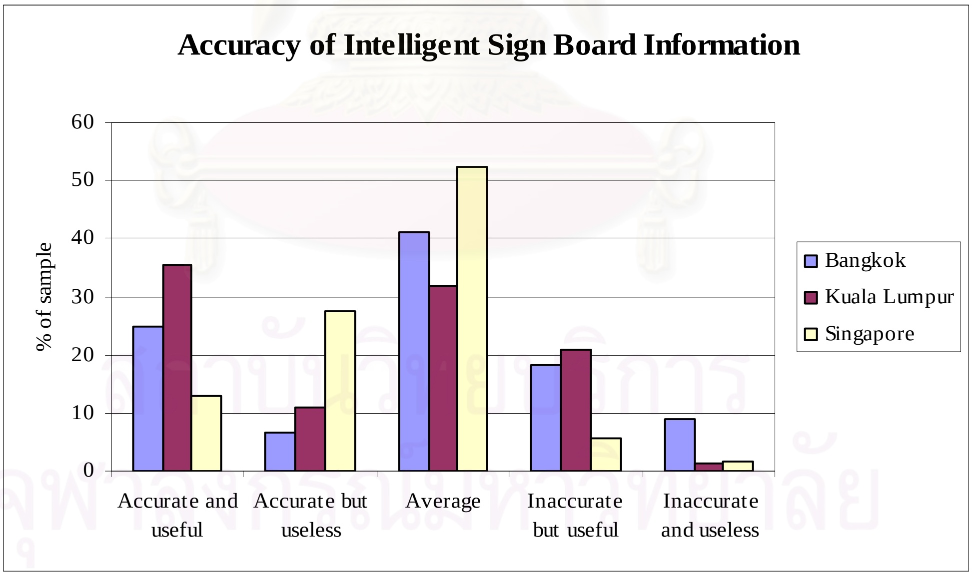


Figure 4.14 Accuracy of Intelligent Signboard

By the questionnaire form, respondents from the three countries were illustrated about how the real system works; then being asked about their opinion about its accuracy. In Singapore and Kuala Lumpur, those cities had shown positive expectations to the device since they do not have this system yet. Despite of the good opinion, Bangkok drivers thought rather different about the device. Most of them said that the accuracy was average, but also quite a number said that the service was inaccurate and useless. This shows that the real condition does not as ideal as the expectation.

In addition, the result from Kuala Lumpur and Singapore might depend on the perceived information from reading and seeing the questionnaire form only (because they had not see the device in person). However, this result still can express the first impression of users pertaining one new technology, and as the evaluation after the system have been deployed for quite some time.

4.4.5. ATIS Devices versus Experience

We compared the device to the initial experience about traffic information for each driver. By result, most of drivers tend to believe more to their experience than the information given by the devices.

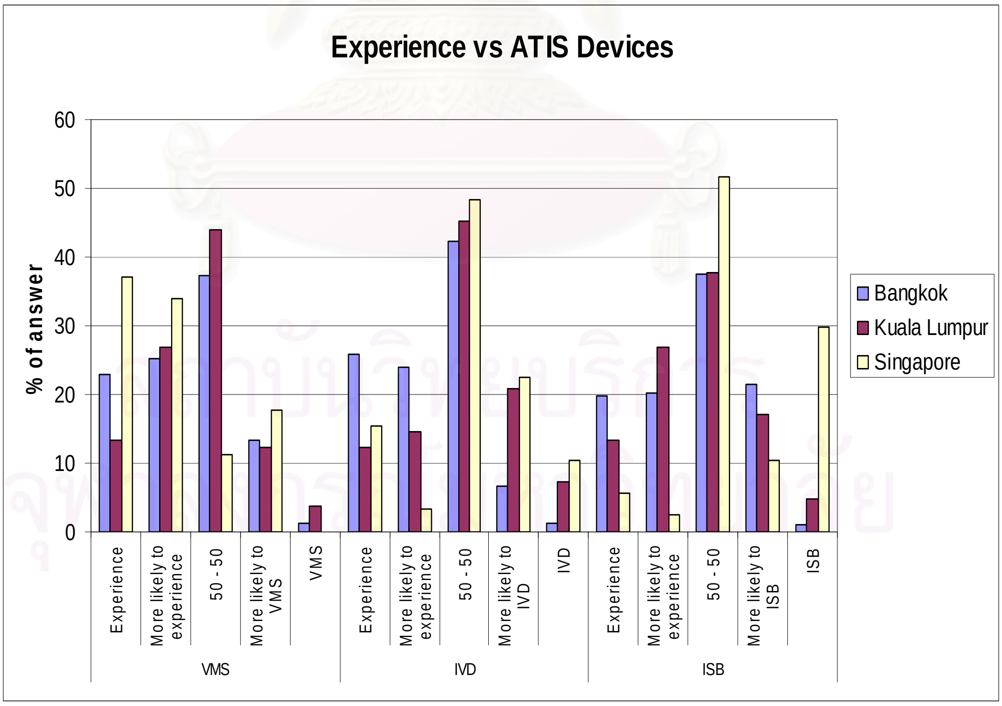


Figure 4.15 Summary of comparison between experience and ATIS devices

As we look to the graph, for VMS device Singapore drivers more likely to trust their experience than the device. Bangkok drivers tend to be neutral, so did Kuala Lumpur drivers. Then, since the user of in-vehicle device were still few, most of drivers in the three cities tend to say they were neutral between the device and the device. The interesting thing on intelligent signboard study that, for drivers in Kuala Lumpur and Singapore who had not experienced this device before, the response was likely neutral to positive. On the contrary, for Bangkok drivers who already experienced the benefit of this device only few of them admit that they believed wholeheartedly on the device. Most of them were answer neutral, or even more to their experience.

The conclusion that we can get from the graph is the availability of the information must be supported by the initial knowledge about the traffic information itself. At this time, traffic information still act as a complement but not as a substitute to the personal experience of traffic conditions on the road. In addition, this situation can be noted as a benchmark in effort to keep improving the quality of traffic information so the level of trust from driver to the ATIS devices can be increases.

4.5. CROSS RELATIONSHIP

Within this sub chapter, we would like to investigate the diversion propensity of drivers according to their personal socio-economic characteristics. We tried to prove the previous literature review regarding the influence of socioeconomic characteristic towards diverting behavior also tried to acquire the individual pattern of each specific city. The diversion propensity acquired by asking respondents whether they would change the route or not when they were offered two identical alternatives between main and alternate route. T-test was carried out on to the variables that paired in the cross relationship in order to test whether the two variables were different or not. The test yielded that we can reject the null hypothesis, which means that each group has difference in its mean.

4.5.1. Change Route Behavior based on Gender

From results of previous studies (e.g. Mahmassani and Yu Hsin Liu in 1999), suppose that male drivers are likely to divert than female drivers. Our study yielded that the change route behavior of female and male drivers was generally equal. The proportions of diverting drivers between male and female were likely similar. In Bangkok, the number of male drivers exceeded the female ones but not in significant numbers.

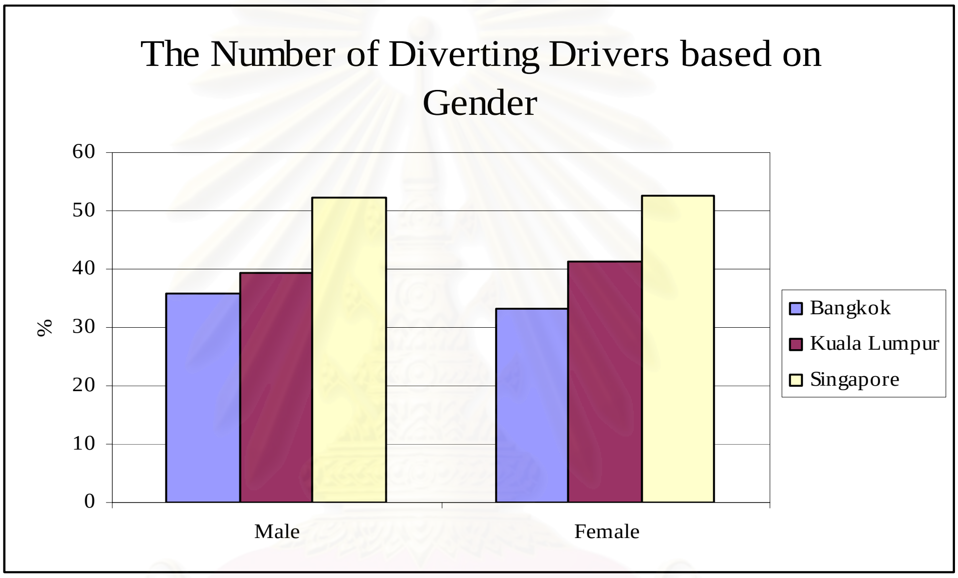


Figure 4.16 Summary of diversion propensity based on gender group

This condition showed that the changing route behavior might not directly related to gender characteristics but also need some additional consideration such as the characteristics of the trip itself. Drivers with different gender could result into the same decision if they were facing the same situation and the same affecting factors. We can also conclude that, the change route behavior of three focused cities was indifferent to gender.

4.5.2. Change Route Behavior based on Age

As presented in the graph 4.17 below, the tendency of diverting behavior are different for the three cities. For Bangkok case, drivers who less than 25 years old tend to divert than other age groups. In Kuala Lumpur, drivers who between 25 and

35 years old proved to be risk prone while older drivers (35 to 45 years old) in Singapore were tend to divert than other age groups. For drivers aged 45 to more than 50 years old, they tend to be risk averse than the other age group in the three cities. This could prove that young drivers were more willing to take risk than older drivers are.

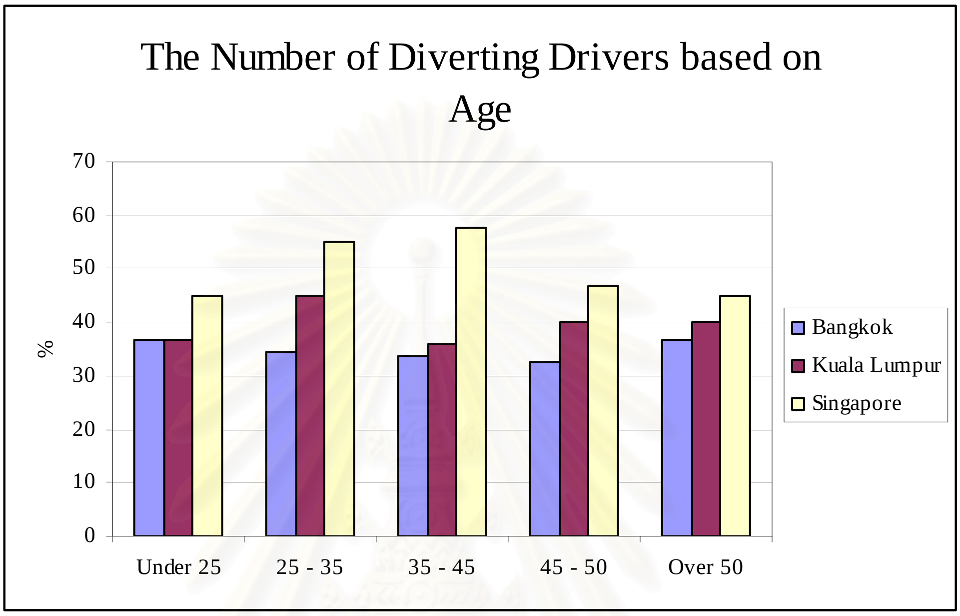


Figure 4.17 Summary of diversion propensity based on age group

4.5.3. Change Route Behavior based on Income

Results from the diversion propensity based on income group were summarized in Figure 4.18. As wee see on the graph, for the three cities, the distribution of diverting drivers were not focused in one group of income only. Low-income drivers in Bangkok tend to divert more than the higher ones, but on the contrary in Kuala Lumpur the highest income class was more likely to divert compared to the others. Then, Singapore drivers were more likely similar to Bangkok case, but, the proportion of diverting behavior through out the income classes were generally the same.

The survey result shows that the characteristic of income was not a certain factor in determining whether the driver within specific income group would divert or not. However, the bias distribution of income might be one of determining factors that makes the income factor insignificant.

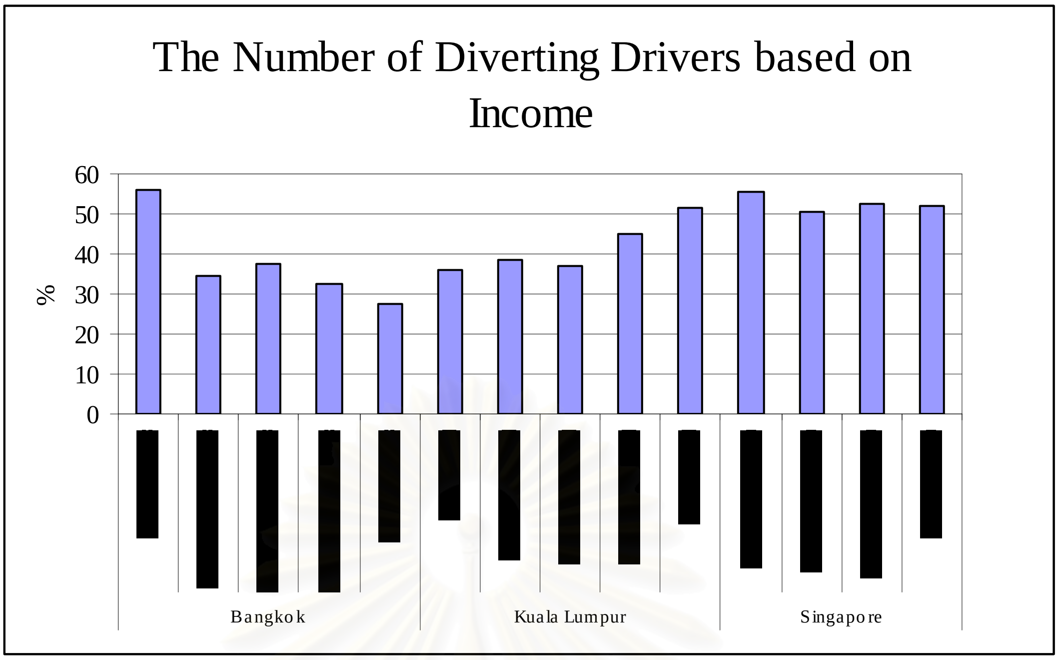


Figure 4.18 Summary of diversion propensity based on income group

4.5.4. Change Route Behavior based on Flexibility

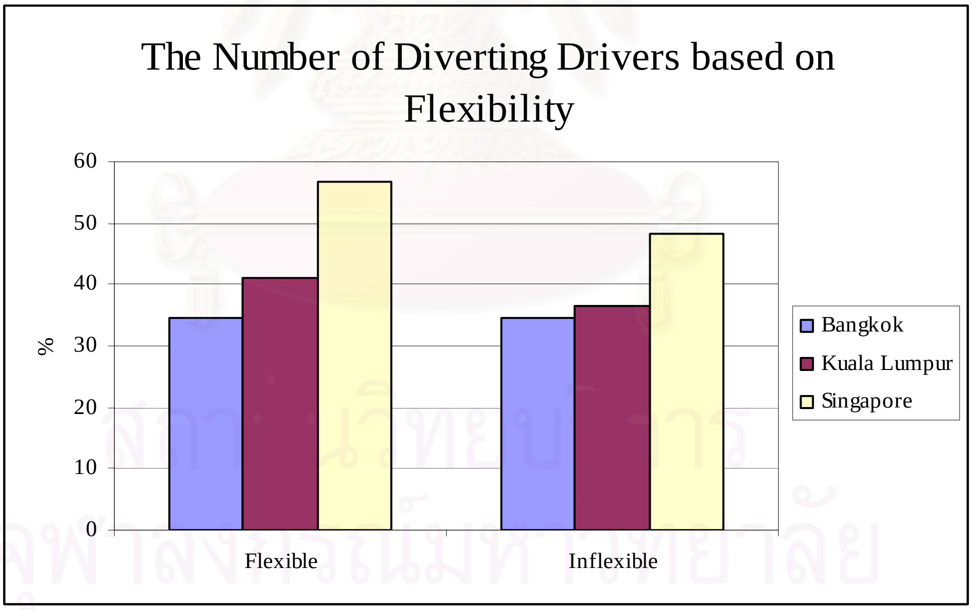


Figure 4.19 Summary of diversion propensity based on flexibility

On Figure 4.19 above, we tried to obtain the relationship between diverting behavior with flexibility in working hour. By looking to the graph, we can see that drivers with flexible working hour tend to be more willing to change their route than those with fixed working hour. Significant differences between flexible and fixed drivers were indicated by Singapore drivers, while for the other cities, especially Bangkok the proportion were generally similar.

4.5.5. Change Route Behavior based on Familiarity on Alternate Route

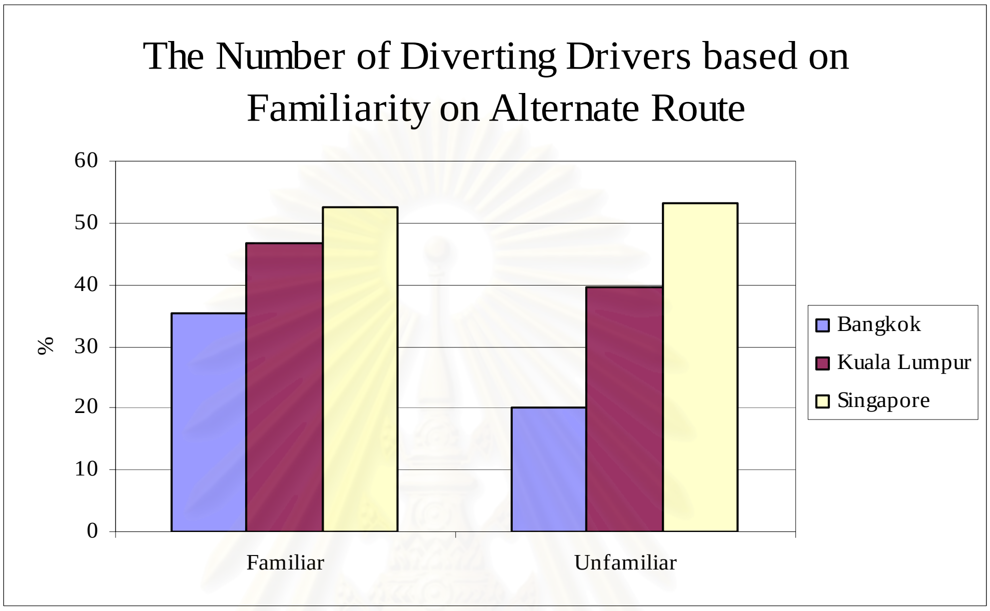


Figure 4.20 Summary of diversion propensity based on familiarity

The figure above presents the relationship between diverting behavior and familiarity on alternate route. We can see that the number of diverting drivers who familiar on their alternate routes exceeded the unfamiliar ones, beside for Singapore which the proportion were likely equal. It proved that the more familiar drivers to their alternate route, the more willing for them to change to alternate route.

4.5.6. Change Route Behavior based on VMS Accuracy

From the Figure below, we can see that most of drivers who divert in the three cities said that the quality of accuracy in VMS information were average to accurate. This could indicate that for diversion activity, drivers were likely seeing VMS as one of consideration for them to change their route also this may be a good indicator about performance evaluation of VMS systems.

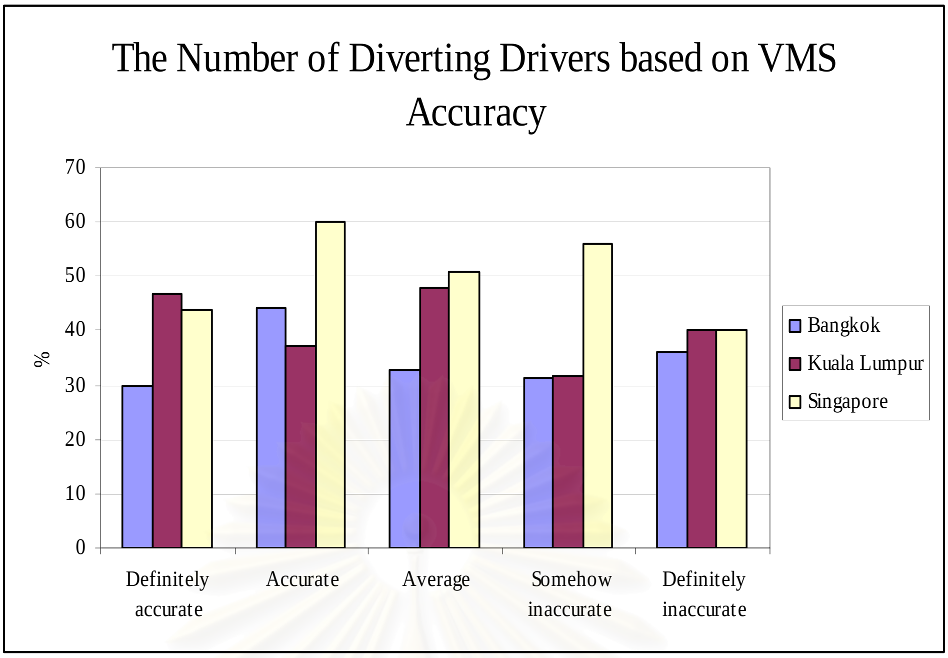


Figure 4.21 Summary of diversion propensity based on VMS accuracy

From the cross relationship analysis, we can have some prior interpretation (before stepping into modeling process) that gender variable was indifferent in choice route behavior, and this variable may not gives a great explanation in the modeling process. On the other hand, for other discussed variables, they were indicating some affects to the change route behavior and it may be interesting to put some of these variables into the model.

These analysis could also proved that, in order to determine the traffic decisions, some trip and personal characteristics did matter or involved in the decision process. However, not all the characteristics could explain the pattern of the process, as it also depends on the unique condition or customs on the study locations. The uniqueness of one location could be easily seen from the predicted behavior model, which would be estimated on the following chapter.

CHAPTER V

MODEL DEVELOPMENT

5.1. INTRODUCTION

The idea of modeling behavior into utility function had been discussed previously in chapter 2. Utility function could be used as the measure of respondents' propensity to each discrete choice portrayed by hypothetical scenarios. The function will reflect the impact of respondents' preferences or stated intentions by their own attributes that included in the exercise. The common formulation of utility function is written as:

$$U_i = \beta_0 + \beta_1.X_1 + \beta_2.X_2 + ... + \beta_n.X_n + \varepsilon_i \qquad (5.1)$$

Where U_i = utility of choice i,

β_0 = constant variable,

$\beta_{1...}\beta_n$ = model coefficients,

$X_{1...}X_n$ = values of attributes, and

ε_i = disturbances.

The objective of the analysis is to acquire the estimated values for *βs* value as "preference weights" and the significance of the model as well. Discrete choice models such as logit or probit are the most generally preferred technique in analyzing stated preference cases. For this study, the driver's change behavior was analyzed by binary choice model using binary logit technique.

In fact, probit model is more general compared to logit model. Nevertheless, since logit model has disadvantages such as complex properties, difficult in calibration process, and lack of capable software, logit model has became more popular and already accepted in general for its application.

5.2. MODEL STRUCTURE

Binary logit model was constructed to model of both revealed preference and stated preference cases, with the dependent variable were choices between “detour” and “stay in the route”. The model constructed as a function of travel time variability characteristics (included in stated preference scenarios), individuals characteristics (flexibility in working hour, familiarity on alternate route), travel information characteristics (accuracy of information, confidence on the information compared to personal experience), and socioeconomic characteristics. The base case of both cases model was the propensity to detour.

Binary logit technique was selected to be the model estimator since the choices were discrete and binary between stay or divert only. The choice set of C_n of each respondents consists of divert or not divert alternatives, motivating the use of binary logit model to predict the probability of diverting behavior. The utility functions, which were discussed previously on Chapter 2, given by:

$$U_{in} = V_{in} + \varepsilon_{in}$$
$$U_{jn} = V_{jn} + \varepsilon_{jn} \quad (5.2)$$

Where:

i = alternative representing user diverting,

j = alternative representing user not diverting,

V_{in} = systematic component of the utility of diverting from the current route,

V_{jn} = systematic component of the utility of not diverting from the current route, and

ε_{in} and ε_{jn} = disturbances or random components.

The probability f an individual n diverting is equal to the probability that the utility of alternative *i* (U_{in}) is greater than or equal to the utility of alternative j (U_{jn}). In the current context, the difference in the systematic components can be expressed as follows:

$$V = (V_{in} - V_{jn}) = cons + \beta X_1 + ... + \beta X_n \quad (5.3)$$

Where: *cons* = alternative specific constant corresponding to divert,

X = vector of explanatory variable that may influence a driver's decision to detour, and

β = vector of estimated parameters corresponding to X.

Repeated of what we have discussed in section 3.4.1, some assumptions had been taken for model estimation process, such as:

a. The value of hypothetical stated choice scenarios was obtained from the result based on pilot survey in Bangkok, and it went through generalizing process in order to achieve similar condition for the three cities.
b. Cost value was obtained by interview and some information from land transport authorities in each location.
c. Flexibility, travel time, and distance data that used in the model were the result of the combination of morning an afternoon condition.

5.3. HYPOTHETICAL SCENARIO DEVELOPMENT

To develop suitable arrangements of hypothetical scenarios, a pilot survey was done in Bangkok with two main goals such as:

a. To make sure that respondents could understand the content of the questionnaire, and
b. To gather trip distance, travel time, and variability data in the real condition.

From the 42 respondents of pilot survey, we could illustrate the trip characteristics distribution on a graph as follows:

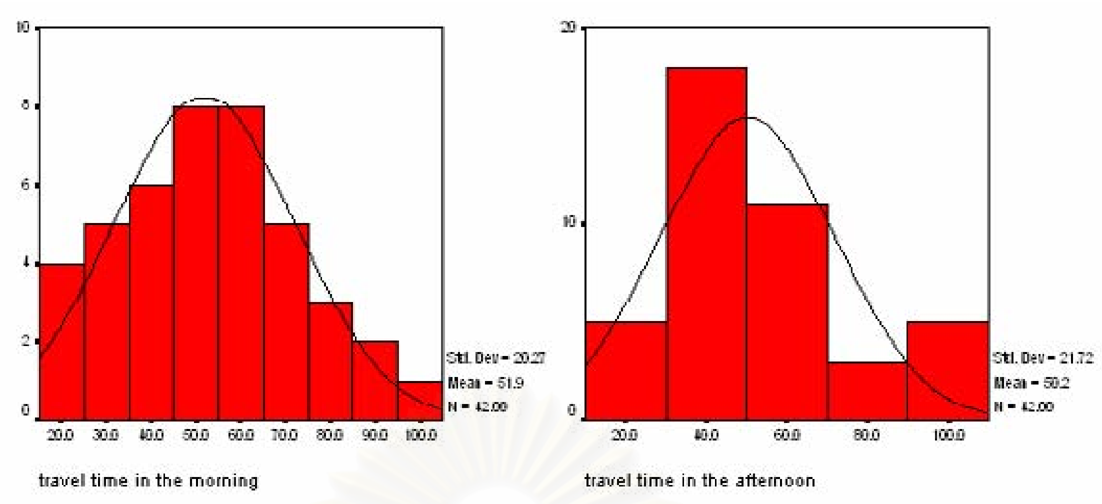


Figure 5.1 Travel time distributions for morning and afternoon trip

For hypothetical scenarios, we tried to vary the travel time and variability in three different levels for the three cities. We would like to have the numbers, which were close to the real condition. Thus, from the result illustrated by the graph, we conclude that in Bangkok for both trip in the morning and the afternoon, in average drivers had about 50 minutes travel time with variability about 20 minutes. Since on the scenarios we tried to simulate the behavior of drivers who are halfway of their trip, then we use travel time 30 – 45 minutes on the scenario and variability of 4 – 16 minutes as the half of the total trip time.

5.4. CONSTRUCTION OF DEPENDENT VARIABLE

The main objective of SP part of the questionnaire was to picture the willingness to divert of drivers due to travel time variability and the willingness to pay for the diversion. As discussed in the previous chapter, the diversion propensities of respondents under various combinations of travel time and money values were recorded into five scales from “definitely stay” until “definitely detour”. However, for the reasons that binary choice model analysis explains the discrete choices as detour or stay only, the five scale of choices would be categorized into two possible actions (stay and divert).

Moreover, there were some possible ways to model the route changing behavior. First, we assumed that the answers “definitely stay”, “probably stay”, or “can not say” were categorized as stay choice, while “probably detour” or “definitely detour” represented the propensity of detouring behavior. For the second case, we assumed that “can not say” was categorized as detour choice, as an opposite on the first case and another one was to exclude the “can not say” answer from the model since it was a bit ambiguous. As we discussed in the previous chapter, Peeta et al. (2000) mentioned on their work, it was not appropriate to follow the second possible way to modeling since “can not say” option was answered by respondents who were in doubt to change their route but more to stay. This could lead to overestimating the final model and resulting in opposite effect.

However, if we abided by the way based on their work, it would result to errors in the estimation process since the size of data were different (see Figure 4.6). Similarly, if we were excluding the “can not say” answer from the model, the model could not be valid since the data in majority people said “can not say” for some questions that they were uncertain. Then, to minimize the errors in the model we followed the way to determine the dependent variable for route changing behavior model for this study as shown in the equation below:

$$y = \begin{cases} 1, \; if \;\; scale\ value \geq 2 \\ \quad 0, \; otherwise \end{cases} \tag{5.4}$$

Which 0, and 1 represented “definitely stay”, and “probably stay”, while 2, 3 and 4 represented “can not say”, “probably detour” and “definitely detour” respectively.

To discover the effects of hypothesized factors on diversion propensity, we categorized the independent variables used in model estimation into sets:

a. *Dummy variables*, differences between relative pairs of SP questions were modeled using dummy variables as applied in “divert” and “stay” choices above.
b. *Reported variables*, to account the differences between individuals concerning their attributes, individual attributes including route and trip attributes were used as explanatory variables.

5.5. STATED PREFERENCE SURVEY RESULTS

Table 5.1 Detail description of the scenarios (cases)

Scenario	Route	Route Description	Travel Time		Associated Cost	Observed Choices (% of sample)		
			Mean (min)	St. Deviation (min)		Bangkok	Kuala Lumpur	Singapore
1	Main	27 min 4 days/week	30	4	0	83	79.27	65.32
		35 min 3 days/week						
	Alternate	27 min 4 days/week	30	4	0	17	20.73	34.68
		35 min 3 days/week						
2	Main	22 min 4 days/week	30	10	0	95.5	92.5	73.33
		40 min 3 days/week						
	Alternate	25 min 3 days/week	35	10	n*	4.5	7.5	26.67
		43 min 4 days/week						
3	Main	21 min 5 days/week	30	16	0	51	65	46.33
		54 min 2 days/week						
	Alternate	16 min 2 days/week	40	16	2n	49	35	51.67
		49 min 5 days/week						
4	Main	12 min 2 days/week	35	16	0	91.5	75	26.67
		44 min 5 days/week						
	Alternate	22 min 4 days/week	30	10	0	8.5	25	73.33
		40 min 3 days/week						
5	Main	34 min 2 days/week	40	4	0	74	57.5	35
		42 min 5 days/week						
	Alternate	32 min 4 days/week	40	10	n	26	42.5	65
		50 min 3 days/week						
6	Main	32 min 4 days/week	35	4	0	36	35.71	15.63
		40 min 3 days/week						
	Alternate	12 min 2 days/week	35	16	n	64	64.29	84.34
		44 min 5 days/week						
7	Main	25 min 3 days/week	35	10	0	51.5	73.81	45.31
		43 min 4 days/week						
	Alternate	34 min 2 days/week	40	4	2n	48.5	26.19	54.69
		42 min 5 days/week						
8	Main	32 min 4 days/week	40	10	0	26	21.43	12.5
		50 min 3 days/week						
	Alternate	21 min 5 days/week	30	16	0	74	78.57	87.5
		54 min 2 days/week						
9	Main	16 min 2 days/week	40	16	0	64	69.05	78.13
		49 min 5 days/week						
	Alternate	32 min 4 days/week	35	4	n	36	30.95	21.88
		40 min 3 days/week						

Notes: *n = 20 baht for Bangkok; 3 ringgit for Kuala Lumpur, and 1 SGD for Singapore case

Table 5.1 presents the comprehensive comparison of travel time and cost parameters between main and alternate routes. Respondents were given nine different scenarios, which compared the properties of main and alternate routes that comprised the combination of travel time and associated cost in a week timeline. The combination of travel time was the result of the combination between average travel time and travel time standard deviation, and the cost only addressed to alternate route since in the earliest chapter we assumed that alternate route could be expressway or highway (which requires additional toll cost). Observed choices were categorized the five choices of diversion propensity and later grouped into binary choices; divert and stay by following the way explained in previous section.

The detail results of the SP survey for the three locations are illustrated in Table 5.2 to Table 5.4 below.

Table 5.2 Detail results for SP survey for Bangkok

	Answers (%)				
	Definitely stay	**Probably stay**	**Can not say**	**Probably detour**	**Definitely detour**
Scenario 1	71	12	13.5	0.5	3
Scenario 2	82	13.5	3.5	0.5	0.5
Scenario 3	34.5	16.5	35.5	9.5	4
Scenario 4	63	28.5	5.5	0	3
Scenario 5	45	29	21	1.5	3.5
Scenario 6	23	13	26.5	24	13.5
Scenario 7	35.5	16	42.5	5	1
Scenario 8	18.5	7.5	23.5	28	22.5
Scenario 9	49	15	27	6	3

Table 5.3 Detail results for SP survey for Kuala Lumpur

	Answers (%)				
	Definitely stay	**Probably stay**	**Can not say**	**Probably detour**	**Definitely detour**
Scenario 1	43.9	35.37	3.66	15.85	1.22
Scenario 2	40	52.5	5	2.5	0
Scenario 3	20	45	12.5	15	7.5
Scenario 4	35	40	15	5	5
Scenario 5	22.5	35	20	20	2.5
Scenario 6	19.05	16.67	16.67	40.48	7.14
Scenario 7	52.38	21.43	11.9	11.9	2.38
Scenario 8	0	21.43	21.43	35.71	21.43
Scenario 9	47.62	21.43	14.29	14.29	2.38

Table 5.4 Detail results for SP survey for Singapore

	Answers (%)				
	Definitely stay	**Probably stay**	**Can not say**	**Probably detour**	**Definitely detour**
Scenario 1	31.45	33.87	25	7.26	2.42
Scenario 2	48.33	25	11.67	11.67	3.33
Scenario 3	0	36.67	11.67	36.67	15
Scenario 4	0	16.67	10	20	53.33
Scenario 5	25	10	30	30	5
Scenario 6	1.56	14.06	14.06	32.81	37.5
Scenario 7	31.25	14.06	34.38	20.31	0
Scenario 8	1.56	10.94	9.38	28.13	50
Scenario 9	67.19	10.94	10.94	7.81	3.13

By looking the results presented on Table 5.2 until Table 5.4, we can obviously see that the data was a bit misleading and provide some uncertainties showed by the inconsistent answer for some cases, which we can easily determine the trend from the scenario description provided in Table 5.1 previously. In order to avoid errors root from this uncertainty, we ‘cleanse’ the data by eliminating the uncertain answers and some hesitated respondents. Misleading answers from the second and third scenarios were the benchmark for the cleanse process.

Based on the data that ‘clean’ already, we could present its statistical properties as shown by Table 5.5 and Table 5.6 below. Note that the number of respondents represent the numbers of data utilized in the process (the survey was using repeated measurement technique, which one respondent practically answered nine different scenarios)

Table 5.5 Explanatory variables in the drivers’ response model

Variables	Category assigned to variable	Mnemonics	Respondents (%)			Remarks
			Bangkok	Kuala Lumpur	Singapore	
Constant	0, if stay 1, if divert	cons				
Gender	0, if female 1, if male	gen	51.54 48.46	28.47 71.53	58.47 41.53	Alt. Spec. Socio
Age	0, if > 50 1, if 45 - 50 2, if 35 - 45 3, if 25 - 35 4, if < 25	age	2.54 10.54 28.62 43.08 15.23	7.29 9.38 9.72 32.99 40.63	6.83 9.56 15.57 43.44 24.59	Alt. Spec. Socio
Income	0, if class 1 1, if class 2 2, if class 3 3, if class 4 4, if class 5	inc	9.62 22.62 26.23 25.31 16.23	31.94 36.46 12.85 5.9 12.85	24.59 31.42 36.07 6.83 1.09	Alt. Spec. Socio
Flexibility of working hour	0, if fixed 1, if flexible	flex	31.77 68.23	28.82 71.18	60.66 39.34	Alt. Spec. Divert
Availability of alternate route	0, if not available 1, if available	av_alr	37.46 62.54	49.31 50.69	62.3 37.7	Alt. Spec. Divert
Familiarity in alternate route	0, if strange 1, if familiar	fam	6.69 93.31	22.22 77.78	5.74 94.26	Alt. Spec. Divert
VMS accuracy	0, if definitely inaccurate 1, if somewhat inaccurate 2, if average 3, if accurate 4, if definitely accurate	vms_acu	4.77 14.08 57.54 20.77 2.85	0 19.44 36.81 37.85 5.9	7.38 25.68 30.6 24.32 12.02	Alt. Spec. Divert
Trip distance		dist				Generic
Trip travel time		tt				Generic
Difference in travel time	TT_{alt} - TT_{main}	d_tt				Generic
Difference in travel time standard deviation	St. Dev TT_{alt} - St. DevTT_{main}	d_stdev				Generic
Difference in cost between main and alternate route	$Cost_{alt}$ - $Cost_{main}$	d_cost				Generic
Number of respondents	N		1300	288	366	

Table 5.6 Descriptive Statistics of variables in diversion propensity model

		Average	St. Dev	Max	Min	N
Bangkok	Distance (km)	16.16	8.49	42	1	1300
	Travel time (min)	49.86	19.90	120	10	1300
KL	Distance (km)	15.42	14.19	70	1	288
	Travel time (min)	40.78	24.03	90	5	288
Singapore	Distance (km)	15.48	13.75	65	2	366
	Travel time (min)	23.52	10.26	52.5	7.5	366

From the result presented by Table 5.5 and table 5.6, we can note that in average, Singapore drivers traveled the shortest distance and time that other cities. If we relate this situation to the SP results presented in Table 5.1, we can conclude that Bangkok drivers considered the cost as a part of their taking risk behavior. Obvious instances as scenario 5 showed that Bangkok drivers tend to chose routes without additional cost, especially for routes that had insignificant difference in travel time and variability. For Kuala Lumpur and Singapore cases, drivers were more determined to combinations of travel time and variability only. If the cost of detour was insignificant, they prefer to detour than stay. For some scenarios that had distinct benefit in travel time and its variability, or higher risk taking situation, Bangkok drivers changed their behavior to be more willing to pay, the same as Kuala Lumpur and Singapore drivers.

Table 5.7 to Table 5.9 show the correlation matrix of variables for all models. Correlation matrix was useful to know whether one variable has high or low correlation with other variables. For variables that appear to be highly correlated, we cannot put them altogether in one model since it would affect biases to the model.

Table 5.7 Correlation Matrix for Bangkok variables

	gen	age	inc	av_alr	fam	vms_acu	flex	dist	tt	d_tt	d_stdev	d_cost	div
gen	1												
age	-0.176	1											
inc	0.148	-0.682	1										
av_alr	0.149	0.033	-0.164	1									
fam	-0.067	-0.034	0.164	-0.918	1								
vms_acu	0.113	-0.051	0.169	-0.049	0.039	1							
flex	0.212	0.112	0.084	0.059	-0.052	0.055	1						
dist	0.165	-0.233	0.059	0.139	-0.097	-0.047	-0.078	1					
tt	-0.024	0.112	-0.135	0.077	-0.091	-0.237	0.133	0.342	1				
d_tt	-0.062	0.040	-0.163	0.064	-0.071	-0.095	-0.084	0.018	0.064	1			
d_stdev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	1		
d_cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.756	-0.151	1	
div	0.078	-0.105	0.219	-0.045	0.055	0.119	0.032	-0.022	-0.133	-0.275	-0.209	0.103	1

By looking the table above, we can identify that AGE and INC variables were highly correlated, as well as FAM with AV_ALR and D_COST and D_TT. These variables might be inappropriate to appeared in the same utility model, but we should remember that is not a guarantee that these variables could not produce a significant model by combining correlated variables since the model that we were trying to estimate was logit model not linear regression model.

Table 5.8 Correlation Matrix for Kuala Lumpur variables

	gen	age	inc	av_alr	fam	vms_acu	flex	dist	tt	d_tt	d_stdev	d_cost	div
gen	1												
age	-0.068	1											
inc	0.009	-0.593	1										
av_alr	-0.022	-0.106	0.065	1									
fam	-0.078	0.086	-0.019	0.325	1								
vms_acu	-0.147	-0.091	0.027	-0.034	-0.095	1							
flex	-0.181	0.111	0.122	-0.014	0.010	-0.144	1						
dist	0.010	-0.244	0.059	0.187	-0.036	-0.113	0.044	1					
tt	0.047	-0.193	0.234	0.302	-0.024	-0.233	0.061	0.772	1				
d_tt	0.025	-0.061	-0.015	-0.058	-0.086	0.059	-0.002	0.081	0.040	1			
d_stdev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	1		
d_cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.746	-0.124	1	
div	0.022	0.062	0.073	0.108	0.024	-0.035	0.043	-0.091	0.018	-0.373	-0.300	0.224	1

For diversion dependant variable (DIV) do not have significant correlation with any variables. One remarkable thing for Kuala Lumpur case, as shown with highlighted cells, high correlation was shown between socio-economic characteristics income (INC) and age (AGE) variables, as well as the distance (DIST) with travel time (TT) variable. As in Bangkok case, D_COST and D_STDEV also had shown high correlation between one another.

Table 5.9 Correlation Matrix for Singapore variables

	gen	age	inc	av_alr	fam	vms_acu	flex	dist	tt	d_tt	d_stdev	d_cost	div
gen	1												
age	-0.250	1											
inc	0.081	-0.680	1										
av_alr	-0.107	-0.068	0.058	1									
fam	-0.078	0.006	-0.038	0.071	1								
vms_acu	-0.040	0.193	-0.031	-0.190	-0.129	1							
flex	-0.055	-0.254	0.142	0.066	0.199	0.053	1						
dist	0.080	-0.535	0.347	0.461	0.088	-0.220	0.315	1					
tt	0.073	-0.497	0.311	0.477	0.082	-0.209	0.287	0.961	1				
d_tt	-0.024	0.025	-0.025	0.037	0.012	0.031	-0.014	0.026	0.021	1			
d_stdev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	1		
d_cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.788	-0.219	1	
div	-0.048	0.007	0.010	-0.034	0.023	0.009	0.043	-0.051	-0.029	-0.292	-0.404	0.164	1

The same situation found for Singapore case. However, the number of correlation cases occurred more frequent than in Kuala Lumpur. Shown by the highlighted cells, it was obvious that income (INC) and distance DIST) variable were highly correlated. It was found as well, for the city the distance and travel time were highly correlated with each other. Moreover, cost variable for both cities were highly correlated with the difference of travel time between main and alternate route.

5.6. ANALYSIS OF MODELS

5.6.1. Coefficient Estimation

As a first step in the model-building procedure, a general model was constructed with the survey data (nine scenarios per respondents = nine times repeated measurements). STATA SE 8.2 was utilized to estimate the coefficient of the models. An expectation according to the sign was employed to determine the most satisfactory variables in the model. A stepwise method was carried out in order to eliminate insignificant variables. The process of variable elimination was applied firstly on the wrong signed variables, and then it continues to the variables that have low t-statistic value.

Table 5.10 Coefficient estimation for route changing model

Variable	Bangkok	Kuala Lumpur	Singapore
	Coeff.(t-ratio)	Coeff.(t-ratio)	Coeff.(t-ratio)
inc	0.290 (5.34)		
vms_acu	0.182 (2.26)		
d_tt	-0.184 (-9.69)	-0.216 (-5.34)	-0.223 (-6.2)
d_stdev	-0.063 (-8.13)	-0.086 (-5.04)	-0.125 (-7.87)
d_cost	-0.043 (-6.15)	-0.178 (-1.97)	-1.124 (-4.05)
constant	-1.486 (-5.36)	-1.556 (-4.55)	-1.210 (-3.64)
sample size	1300	288	366
L(0)	-844.734	-183.316	-253.342
L(β)	-722.578	-147.565	-198.341
ρ^2	0.1446	0.195	0.2171
corrected ρ^2	0.1387	0.1787	0.2053

Table 5.10 presents the most satisfactory and significant model of changing behavior in the three cities. Furthermore, all models were significantly estimated for 95% level of confidence.

As we see on the table, we can have some initial interpretation from the model estimation for the three cities as follows:

a. The influence of socio-economic variables could not explain much of the behavior in the model for all locations.
b. For Kuala Lumpur and Singapore case, only stated preference properties did matter in determining whether an individual would like to detour to their alternate or not.
c. The behavior of changing route in the three cities was sensitive to travel time variability and its associated cost.

For Bangkok, we can rewrite the model estimated as follows:

$$V_{divert} = -1.486 + 0.290\ INC + 0.182\ VMS\_ACU - 0.184\ D\_TT - 0.063\ D\_STDEV - 0.043\ D\_COST \quad (5.5)$$

As we can see from the model above, the diverting behavior in Bangkok were influenced by socioeconomic characteristics (income), and travel time variability factors (difference in travel time, standard deviation of travel time, and cost) only. The positive sign of income variables indicated that high-income drivers were more likely to divert.

For travel time variability characteristics, the signs of difference in average travel time, difference in standard deviation of travel time, and difference in cost between alternate and main route showed the right sign, which was negative. This means that when the difference of the options between alternate and main route decreased, people tend to divert than stay in main route.

In Kuala Lumpur, the estimated model of diverting behavior was different with Bangkok model. We can rewrite the model as:

$$V_{divert} = -1.556 - 0.216\ D\_TT - 0.086\ D\_STDEV - 0.178\ D\_COST \qquad (5.6)$$

Compared to Bangkok, socio economic characteristics were not playing a significant role or specific behavior in model estimation for Kuala Lumpur. This could be shown that no socioeconomic yet individual characteristics were utilized in the model since those variables were not significant.

As the result, we can conclude from the model that the behavior of changing route in Kuala Lumpur only affected by travel time variability properties. Since it were not significant at all to be put in the model, we can say that gender, income, and age characteristics did not influence much in determining travel decisions. All trip characteristics such as flexibility and influence of traffic information did not affect much in the decision making process. Similar with Bangkok model, all the stated preference variables were showing negative signs.

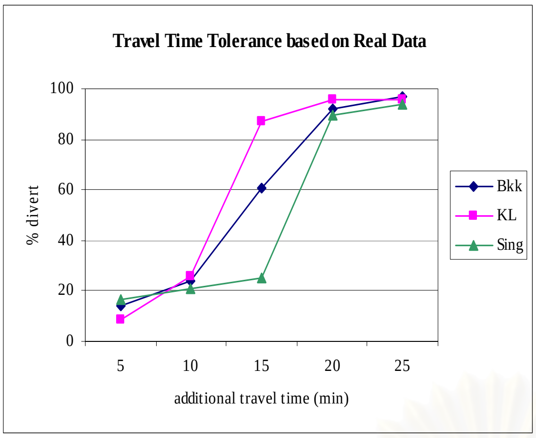
Corresponds to the previous cities, for Singapore case the model can be rewrite as:

$$V_{divert} = -1.210 - 0.223\ D\_TT - 0.124\ D\_STDEV - 1.124\ D\_COST \qquad (5.7)$$

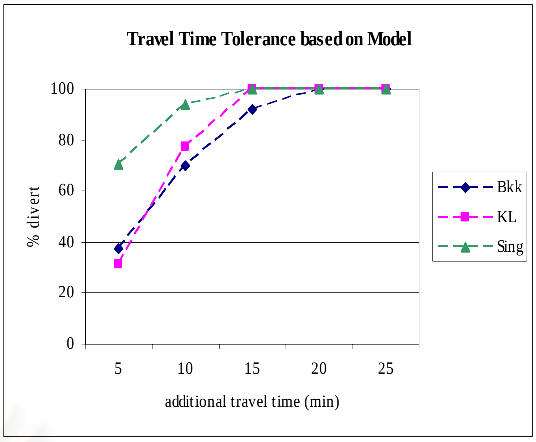
As we can see from the model estimated, Singapore's change route behavior was not influenced with socioeconomic characteristic at all similar as Kuala Lumpur. None trip or personal characteristics counted in the model instead of travel time characteristics. It means that, the behavior and change route decision process in Singapore determined only by the characteristics of the choices itself. The socio-economic and even previous experiences on the trip did not affect to the decision taken.

5.6.2. Travel Time Tolerance Estimation

Previously on chapter 4, we presented the travel time tolerance of drivers classified by trip distance. By doing the same procedure using predicted model, we can illustrate the travel time tolerance, again, based on the estimated model as shown on the figure below.



(Figure 5.2.a)



(Figure 5.2.b)

Figure 5.2.a and **Figure 5.2.b** Travel time tolerance based on real data and model prediction

Figure 5.2.a portrays the delay tolerance based on the real data gathered from the survey while Figure 5.2.b shows the predicted number of diverted drivers from the model. By looking to the graphs, we can see that the model predicted drivers to be far more sensitive on delay compared to the real situation.

For a particular length of delay, the model predicts the drivers to be more sensitive as we can see from the difference on the percentage of drivers who divert into their alternate route. This shows that the model are tend to predict the drivers to be more risk aware and sensitive to the delay attached to their travel time. Again, if we compare the behavior from the three cities, we can clearly see from the model that Singapore drivers were more sensitive to additional delay than the other two cities.

5.6.3. Travel Time Variability Estimation

Using the same approach, we can also draw the diversion propensity based on the estimated model to analyze the impact of travel time variability on route change behavior. By plot various numbers of travel time variability to the model, we can obtain the trends as shown on Figure 5.3 below.

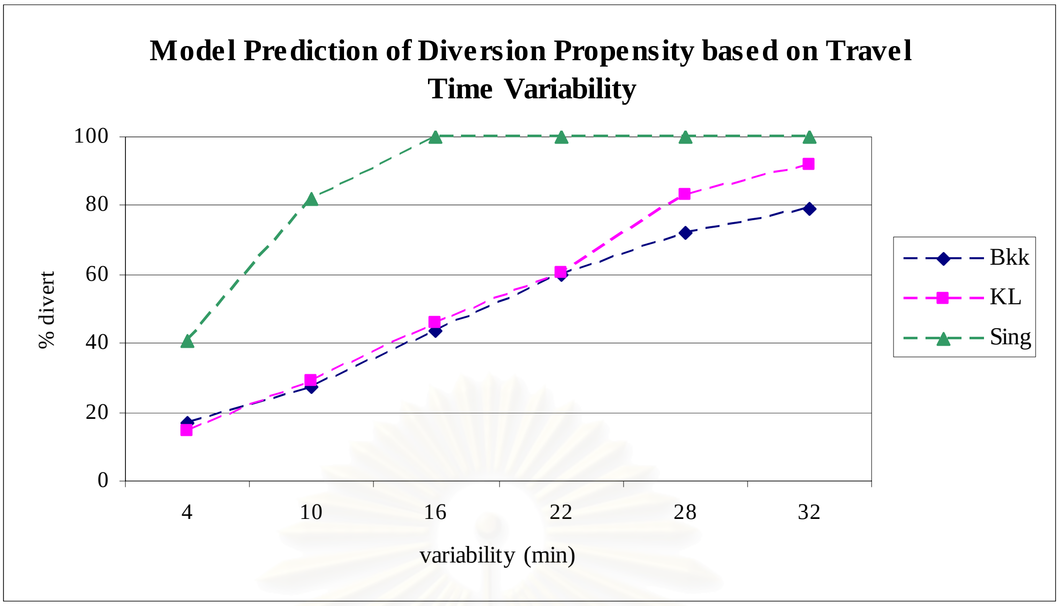


Figure 5.3 Diversion propensity based on travel time variability

As we can see from the figure, when we focused on travel time variability, the pattern of diverting behavior from the three study locations were similarly shaped as logarithmic trend line. The variability here defined as the difference of variability between main route and alternate route. It means that, the higher travel time variability on main route caused the higher number of drivers who decide to divert to another route. When we compared the behavior among the study locations, we can conclude that Singapore drivers still the one whom most sensitive to variability in travel time compared to the others, as shown as the number of diverted drivers that was the highest among all for a particular variability. By additional variability about 4 minutes on their travel time, 40 percent of drivers decided to divert and it was increased about twice when variability reached 10 minutes. On the other hand, Bangkok and Kuala Lumpur drivers seemed to have the same reaction toward variability shown by the similar percentage of diverted drivers.

From the two illustrations above, we can conclude the behavior of drivers in the three cities based on the model estimation. We can sum up the conclusion as follows:

a. The estimated model tends to predict the behavior of drivers in the three cities to be risk aware, or sensitive to delays and variability added to their travel time.

b. The more delay or variability occurred on the trip, the more tendencies for drivers to divert to other alternative route(s).
c. Singapore drivers were the most sensitive to delay on travel time and variability on their travel time.

5.6.4. Trade-off Variables

5.6.4.1.Value of Time

As stated in Ben Akiva and Lerman (1985), a ratio of two coefficients implicated in the same utility function provides information about a trade off or marginal rate of substitution. As an instance, for the three cities we can obtain the value of trade off between difference of cost and difference of average travel time between main and alternate route variables as driver's value of time by following the equation below:

$$\text{Value of time} = \frac{Coeff.\,of\ d\_cost}{Coeff.\,of\ d\_tt} \quad (5.8)$$

From the equation above, we can get the value of time for each city as:

Bangkok: $$VOT_B = \frac{-0.043}{-0.184} = 0.23 \text{ THB/minute} \quad (5.9)$$

Kuala Lumpur: $$VOT_{KL} = \frac{-0.178}{-0.216} = 0.82 \text{ RM/minute} \quad (5.10)$$

Singapore: $$VOT_S = \frac{-1.124}{-0.223} = 5.04 \text{ SGD/minute} \quad (5.11)$$

From the three value of time, we can conclude that drivers in Singapore have the highest respect of the time than all. It means that, a minute saving on average travel time was equal to saving 4.84 SGD by approximately. By other words, Singapore drivers were willing to pay in amount of 4.84 SGD as a compensation of diverting from their main route to alternate route in order to save a minute in their travel time.

Moreover, in Kuala Lumpur they valued a minute of travel time saving only about 0.82 RM while in Bangkok the value of time even lower about 0.23 THB only. Please note that the term of cost here only related into the expenses that drivers would pay as a compensation of travel time variability only, not the whole opportunity cost of diverting.

5.6.4.2.Value of Travel Time Variability

Similarly, using the variables of difference of cost and difference of standard deviation on travel time between main and alternate route, we can get the value of time variability as shown as the equation below:

$$\text{Value of time variability} = \frac{Coeff.of\ d\_\cos t}{Coeff.of\ d\_stdev} \qquad (5.12)$$

The value of time variability for the three cities can be computed as shown below:

$$\text{Bangkok:} \quad VOTV_B = \frac{-0.043}{-0.063} = 0.68 \text{ THB/minute} \qquad (5.13)$$

$$\text{Kuala Lumpur:} \quad VOTV_{KL} = \frac{-0.178}{-0.086} = 2.07 \text{ RM/minute} \qquad (5.14)$$

$$\text{Singapore:} \quad VOTV_S = \frac{-1.210}{-0.125} = 9.68 \text{ SGD/minute} \qquad (5.15)$$

Based on the value that obtained above, still Singapore drivers were the one who valued their time the highest compared to Kuala Lumpur and Bangkok drivers. They were willing to pay equal to 9.68 SGD[2] as compensation in diverting to alternate route in order to reduce one-minute variability on their travel time. Kuala Lumpur drivers tend to pay 2.07 RM and Bangkok drivers were willing to pay in amount of 0.68 THB for the same purpose.

From the models above, it can be seen that for all cases that both expected travel time and variation in travel time does influence route choice. For some cities,

[2] 1 SGD = 2.264 RM = 21.416 THB per April 22, 2007

receiving traffic information was found to have significant effect in the model since the information could reduce the degree of travel time uncertainty and allows them to choose routes more wisely. Moreover, drivers were having a tendency to pay more to reduce or minimize the variability on their travel time than to reduce or minimize the average of the travel time itself. With a simple calculation, Singapore drivers were willing to pay almost twice more (9.68/5.04 = 1.92) to minimize the variability than to reduce their average travel time, and so Kuala Lumpur drivers did. However, by applying the same computation Bangkok drivers were willing to pay approximately 3 times higher for the same purpose.

By looking to the value, it seemed that Bangkok drivers value their time so low while Singapore drivers value it surprisingly high. Regardless some errors during the model estimation, this indicated that Bangkok drivers were more willing to spent their time on the road during some delays on traffic congestion than pay for some value to save it. On the other hand, Kuala Lumpur and Singapore drivers value their time so much that they would like to pay a higher value for saving their travel time.

However, refer to Mackie et al. (2003) work for value of time, we can find that the VOT number for Malaysia and Singapore are a bit unusual and illogical. On their work, they perceived the value of time in UK for car drivers in 2002 was £26.43 per hour[3], which is equal to 28.7 THB/minute. For Singapore case itself, a study conducted by Paul W. Wilson in 1989 with study case Singapore resulted value of time for Singapore was 47 – 49 percent of the wage rate, which was $3.51/hour. From this number we can derive the VOT in Singapore to be $1.72/hour ≈ 2.62 SGD/hour. For Malaysia case, Kamba et al. (2007) implied implicitly on their paper that car drivers have value of time about 0.86 RM/minute, and from a World Bank research by Kenneth M. Gwilliam in 1997, for car drivers in Thailand the value of time equal to 0.82 THB/minute[4].

If we evaluate these numbers with the result for Singapore and Kuala Lumpur, it is obvious that the result for both cities were illogical. Regardless of the low t-statistics value for the models, these situation shows that the effect of cost in trade-off

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[3] 1 GBP = 65.256 THB per April 27, 2007
[4] 1 USD = 32.645 THB per May 9, 2007

technique cannot be explained by the model. This means that in the process of determination of change route, people only consider about the difference in travel time and its variability without look up the effect of the cost. These conditions can be easily explained for Singapore case since the drivers had never experience paying any toll cost except for road pricing, which has different scheme with this situation.

Moreover, the big gap of value of time among the three cities could also a result of possibilities as follows:

a. Difference in valuing a certain amount of money,

   The difference of valuing a certain value of money could result in a gap of value of time among the three cities. For an instance, the way Singapore people value one-dollar money might be different with Bangkok or Kuala Lumpur people value the same amount of money. This is a result of difference in socio economic situation among the cities.

b. Difference in value of time,

   Similar with the point above, the difference in valuing saved travel time might be different from the three cities. This can be indicated by the difference of public transport fares in the three cities for the same distance and facility, although this could be caused by the point above.

c. Difference in lifestyle and habit,

   Difference in lifestyle and habit could be affected to the value of time as well. For the places that require a fixed and intolerable punctuality, the value of time must be higher than places that require schedules that are more comfortable.

However, we need to conduct further study and analysis to prove this assumption. Then, it could be said that variability in travel time is a more important consideration for changing route than the length of the travel time itself. Drivers were more likely to choose routes with reliable travel time since diversion is normally expected to save time (Khattak et al. 1993)

5.6.4.3.Travel Time to Variability Trade-offs

After we got the relationship of percentage of diverted drivers to the increment of average travel time and variability of travel time, it is sufficient to get the value of trade-off between these two values to acquire the number of travel time and variability that will result the same effect to the number of diverted drivers using the formula as:

$$\text{Travel time trade-off} = \frac{Coeff.of\ d\_stdev}{Coeff.of\ d\_tt} \tag{5.16}$$

Where d_stdev is the difference of standard deviation between alternate and main route, and d_tt is the difference of average travel time between alternate and main route.

From the equation above, we can get the value of trade off for each city as:

Bangkok: $$\text{Travel time trade-off}_{B} = \frac{-0.063}{-0.184} = 0.342 \tag{5.17}$$

Kuala Lumpur: $$\text{Travel time trade-off}_{KL} = \frac{-0.086}{-0.216} = 0.400 \tag{5.18}$$

Singapore: $$\text{Travel time trade-off}_{S} = \frac{-0.125}{-0.223} = 0.560 \tag{5.19}$$

The result of trade-off above can be explained that, by increasing the average travel time about 0.3 – 0.6 minute, the effect can cancel out the effect of one-minute variability in travel time. To prove this statement, we can use the model to plot the specific numbers of average travel time and variability as follows:

Bangkok model:

d_tt = 0,342 minute → % of driver who divert = $\frac{45}{1300} \times 100\% = 3.46$ %

d_stdev = 1 minute → % of driver who divert = $\frac{45}{1300} \times 100\% = 3.46$ %

To conclude, for Bangkok case, the effect of one-minute additional variability in travel time can be cancelled out the by reducing the average of travel by 0.773 minute, as if reducing 0.768 minute and 0.635 minute for Kuala Lumpur and Singapore respectively.

5.6.5. Model Validity

The validity of SP cases is a critical issue; while SP techniques are used more in testing new concepts or services, its reliance on hypothetical may raise doubts regarding validity (Khattak et al. 1993). On the other hand, we need to test whether our model are applicable or not by applying the estimated on to the data used (internal validation) or use a sub sample of data that was not used in estimation process as a validation sample (external validation). Then, percentage of true prediction can be used to examine how well the model predicts the real condition.

5.6.5.1.Internal Validation

Percentage of true prediction was used by applying the model into the actual data and compares the prediction with the real data. The value of the predicted model was categorized as:

$$W_n = \begin{cases} 1 & if \ \ P_n(i) \geq 0.5 \\ 0 & otherwise \end{cases} \tag{5.20}$$

Where: W_n = true predicted value of respondent n

$P_n(i)$ = value of probability of respondent i to divert

Then to calculate the percentage of prediction value to true value can be computed following the formula as follows:

$$\% \ correct = \frac{\sum_{n=1}^{N} W_n}{N} \tag{5.21}$$

Where: N = number of data

The frequencies of observed and predicted outcomes for the three cities using diversion model can be seen in table 5.11 to table 5.13.

Table 5.11 Frequencies of actual and predicted outcomes for Bangkok

Final Model			
Observed	Predicted		Total
	Divert	Stay	
Divert	114	54	168
Stay	346	786	1132
total	460	840	1300
Percentage of true prediction			**69.23**

Table 5.12 Frequencies of actual and predicted outcomes for Kuala Lumpur

Final Model			
Observed	Predicted		Total
	Divert	Stay	
Divert	33	63	96
Stay	9	183	192
total	42	246	288
Percentage of true prediction			**75.00**

Table 5.13 Frequencies of actual and predicted outcomes for Singapore

Final Model			
Observed	Predicted		Total
	Divert	Stay	
Divert	125	66	191
Stay	25	150	175
total	150	216	366
Percentage of true prediction			**75.14**

As we see from the table, the model can predict about 69 – 75 percent true for all locations. This means that the model is good enough to predict the actual condition even the value of pseudo R^2 for all models were relatively low.

5.6.5.2.Transferability

Instead of internal validation, we also run transferability analysis to test whether the model that applied in one location could be applicable for other locations as well. For this purpose, we did the transferability in two approaches. First, we applied the model for one location on the other two locations and vice versa and the second approach was by compiled all the data with city indicator as dummy variable. The result of the external validation can be seen on table 5.14 to table 5.16 below.

Table 5.14 Frequencies of actual and predicted outcomes using Bangkok model

Kuala Lumpur				**Singapore**			
Observed	Predicted		Total	Observed	Predicted		Total
	Divert	Stay			Divert	Stay	
Divert	22	64	86	Divert	44	147	191
Stay	9	183	192	Stay	5	170	175
total	31	247	278	total	49	317	366
Percentage of true prediction			**73.74**	Percentage of true prediction			**58.47**

Table 5.15 Frequencies of actual and predicted outcomes using Kuala Lumpur model

Bangkok				**Singapore**			
Observed	Predicted		Total	Observed	Predicted		Total
	Divert	Stay			Divert	Stay	
Divert	453	7	460	Divert	56	135	191
Stay	647	193	840	Stay	8	167	175
total	1100	200	1300	total	64	302	366
Percentage of true prediction			**49.69**	Percentage of true prediction			**60.93**

Table 5.16 Frequencies of actual and predicted outcomes using Singapore model

Bangkok				**Kuala Lumpur**			
Observed	Predicted		Total	Observed	Predicted		Total
	Divert	Stay			Divert	Stay	
Divert	453	7	460	Divert	89	7	96
Stay	647	193	840	Stay	151	41	192
total	1100	200	1300	total	240	48	288
Percentage of true prediction			**49.69**	Percentage of true prediction			**45.14**

As shown in the tables above, we can conclude that not all models were quite general to be applicable in other locations by looking the percentage of true prediction of the model applied in other samples. Some can predict for more than 50 percent true value but as we see on Table 5.15 and Table 5.16, when we applied Kuala Lumpur and Singapore models to Bangkok data set, it only result 49.69 percent true prediction, which was relatively low.

Then, by comparing values in Table 5.14 for Kuala Lumpur and Singapore data set, Bangkok model seemed to predict more drivers to stay than other models. This means that when we applied Bangkok model in other cities, it will predict more drivers who willing to stay than those who willing to divert to another route.

By doing the same comparison to Kuala Lumpur and Singapore models, we also can obtain the characteristics of the two models. Kuala Lumpur model predicted differently for Bangkok and Singapore test case. It predicted more drivers would like to divert for Bangkok but on the other hand it also predicted that majority of Singapore drivers would stay on their route.

Furthermore, an interesting thing could be seen on Table 5.15 and Table 5.16. For Bangkok data set, both Kuala Lumpur and Singapore model predict the same percentage of true value, and even the same value for its error. This could be caused that both Singapore and Kuala Lumpur model only involved travel time characteristics on its estimation so the prediction only depended on the difference on its coefficients only.

Singapore model was good in predicting its own data set; this proved by the percentage of true prediction exceeded 75 percents. However, when it came to predict Kuala Lumpur and Bangkok samples, the percentage of true prediction was dropped to less than 50 percents. We can conclude from this that Singapore model was unique and only capable to model its own data but could not represent other data sets.

From internal validity and transferability analysis, we can achieve a conclusion that some models were specific and unique to predict using its own data, but could not be able to predict other locations behavior. Transferability analysis resulted that Singapore has the most unique and specific characteristics amongst all cities.

Transferability analysis could also be done on combined data set as shown by Table 5.17 below:

Table 5.17 Frequencies of actual and predicted outcomes using all cities model

Bangkok Model				**Kuala Lumpur Model**				**Singapore Model**			
Observed	Predicted		Total	Observed	Predicted		Total	Observed	Predicted		Total
	Divert	Stay			Divert	Stay			Divert	Stay	
Divert	180	567	747	Divert	542	205	747	Divert	667	80	747
Stay	68	1139	1207	Stay	664	543	1207	Stay	823	384	1207
total	248	1706	1954	total	1206	748	1954	total	1490	464	1954
Percentage of true prediction			**67.50**	Percentage of true prediction			**55.53**	Percentage of true prediction			**53.79**

By applying Bangkok model to the data, we obtain that the model predict about 67.5 percent true value, and it was the highest amongst all while Kuala Lumpur predict 55.53 percent and Singapore 53.79 percent true value. This indicated that Bangkok model was the most transferable among the three models.

CHAPTER VI

SUMMARY OF FINDINGS AND CONCLUSION

6.1. SUMMARY OF FINDINGS

Within this study, changing route or diversion propensity behavior defined as the propensity of drivers to change their route from their usual into another route due to several considerations in order to minimize their travel time. This study was trying to develop driver's changing route behavior model that incorporates generalized model of driver's personal characteristics, alternate route characteristics, influence of travel information, and travel time variability for study case three different cities in South East Asian area.

Due to survey process and data limitations, the diversion propensity model considers only for active yet private car drivers. Then, the model explains only the behavior of drivers who had alternate route(s) beside their main route. Most of data obtained from on-site interview. The interview survey was carried out in three different cities from three different countries.

Respondents were asked to answer an eight page long questionnaire, which took around 10 until 15 minutes to complete. The questionnaire consists of questions pertaining personal information and travel characteristics, also nine set of route choice hypothetical scenarios. Since nine hypothetical scenarios in one questionnaire could confusing and lead to biased answers by respondents, then we split the questions into two set of questionnaire each consist of five set of route choice questions.

Some important findings from the survey can be listed as follows:

- ❖ Socioeconomic Characteristics

  By doing cross-relationship analysis to the variables took into account in the modeling process, we found that the behavior of change route was indifferent for male and female drivers. This means for both gender groups, the way of think and behave for change route was generally equal.

- Changing route behavior

  When we focused on diverting behavior, the main reason that makes drivers wanted to divert is to avoid congestion on the road. Observations also indicated that flexibility of working hour does affect to change route behavior. Besides, when there was any traffic information available, they would like to combine the information given by traffic information and their knowledge to decide their further action. However, at the moment traffic information role is still as a complement of personal knowledge of drivers. Then, these situations indicated that the role of traffic information in the future would more and more promising in assisting drivers go through their journey. By applying some enhancement on traffic information system and quality, it is expected to help improve the quality of traffic conditions.

  Furthermore, from model estimation of changing route behavior for the three cities, we found that the behavior of one city with another was different. The trip and socio-economic characteristics did not explain much in the modeling process. Kuala Lumpur and Bangkok drivers influenced by income and availability of alternate route(s) while in Singapore only travel time and cost properties that matters.

- Travel time sensitivity

  The result indicated that commuter drivers showed different attitude towards additional delay in their travel time compared to non-commuter drivers. Commuter drivers were having tendency to be more sensitive to delay than non-commuter drivers do. For instance, with additional 10 minutes delay in travel time, commuters show greater diverting number than non-commuter drivers. This indicates that for long distance drivers, a small delay on their travel time may not affect to divert that much. From the sensitivity analysis, we can also obtain the transition length of delay that makes drivers determined to change their route drastically were about 10 – 20 minutes.

  Thus, by looking the records of late arrival on the three cities, Bangkok drivers experienced more variability in their travel time compared to the other cities, showing by the high number of drivers who experienced delay. By comparing the real condition and model prediction, we achieved that the model predicted drivers to be risk aware; also, it proved that Singapore drivers were sensitive to changes on their travel time.

- Traffic Information development

For all the cities, stated preference study on new traffic information devices showed that the response was positive. These devices having promising future to be implemented, but some further studies need to be performed regarding this issue. On the other hand, most of respondents rated the accuracy of traffic information to be average. This phenomenon indicating that drivers indicated the demand to improve the quality of traffic information thus in the future this system could help travelers better.

Furthermore, the modeling result indicated that traffic information do have a role in change route activity for Bangkok and Kuala Lumpur case.

- Trade off findings

By doing some trade-off on the model we can acquire some findings on value of time. The value that drivers willing to pay for reducing one minute from their experienced travel time as follows:

Bangkok:	VOT_B	= 0.23 THB/minute
Kuala Lumpur:	VOT_{KL}	= 0.82 RM/minute
Singapore:	VOT_S	= 5.04 SGD/minute

From the values above, Singapore drivers proved to have the highest respect of time, indicated by the highest value of time and value of travel time variability. Then, trade-off for obtaining value of reliability in travel time shown as:

Bangkok:	$VOTV_B$	= 0.68 THB/minute
Kuala Lumpur:	$VOTV_{KL}$	=2.07 RM/minute
Singapore:	$VOTV_S$	= 9.68 SGD/minute

From the trade-off result above, it is obvious to see that Singapore drivers are willing to pay higher that the other two cities to reduce uncertainties on their travel time.

By doing the same trade off technique to travel time variables, we can find the relationship between average travel time and travel time variability as shown below:

Bangkok: Travel time trade-off $_{B} = \dfrac{-0.063}{-0.184} = 0.342$

Kuala Lumpur: Travel time trade-off $_{KL} = \dfrac{-0.086}{-0.216} = 0.400$

Singapore: Travel time trade-off $_{S} = \dfrac{-0.125}{-0.223} = 0.560$

From the number above, we can say that to cancel out the effect of one-minute variability on travel time, we can reduce the average travel time by 0.342; 0.4; and 0.56 minutes for Bangkok, Kuala Lumpur, and Singapore respectively.

6.2. CONCLUSION

Travel behavior is a unique occurrence since it is a result of a combination of numbers of factor, which is different from one case to another. Change route activity is one of travel behavior on the road as a reaction to avoid congestion or saving travel time. By analyzing changing route behaviors in Bangkok, Kuala Lumpur and Singapore, we gather some conclusion that the behavior of drivers in three different cities on three different countries were different even they are located in the same region or area. This could be a result of different characteristics, either personal or social among the three locations.

Some similarities on the behavior can be found as a proof that there were some characteristics that shared together by drivers in the three cities. Besides the particular characteristics, traffic information also proved to be one of consideration in changing route behavior. Flexibility of working/school hour was also proved as an influence.

Furthermore, in dealing with travel time variability, model estimation showed that variability in travel time concerned drivers in choosing between stay or change their route. By conducting some cross findings between real time situation (based on the data) and the result predicted by the model, we gather some conclusion about travel time variability as:

a. The estimated model tends to predict the behavior of drivers in the three cities to be risk aware, or sensitive to delays and variability added to their travel time.
b. The more delay or variability occurred on the trip, the more tendencies for drivers to divert to other alternative route(s).
c. Singapore drivers were more sensitive to changes on their travel time compared to the other cities.

From the result of trade-off technique, drivers value reliability in travel time higher than the overall average of travel time, indicated by the value of money that drivers were willing to pay in order to reduce variability was higher that the value for reduce average travel time itself. This variability factor became an inseparable factor from trip characteristics especially for our Bangkok case. This fact can support the belief that Bangkok drivers might need more en-route traffic information to assist them overcome this variability. This may be a great chance to develop the in-vehicle information systems or improve the existing traffic information in the city.

Then, from the model estimated, the effect of variability can be cancelled out by reducing average travel time. This is a fundamental explanation of drivers' tendencies in adjusting their way to drive (e.g. drive faster) in order to overcome the uncertainty during their trip.

However, after skimmed some previous studies and literatures pertaining the same issue, the trade-off value seemed to be illogical by looking to the big gap value of time among the three cities. The way respondents treat the effect of cost variable was different with the initial researcher's expectation. By presenting the cost variable together with time variable, it seems that respondents only consider about the effect of travel time combination instead of its associated cost. When people have good and equivalent trade-off between time and cost variables, the result may yield differently.

Also, the model has very low t-statistics value, which is below 15%. This might be one of the causes of the errors in estimation process.

Regardless of some errors occurred on the model estimation this could be a result of some conditions as follows:

a. Difference in valuing a certain amount of money,
b. Difference in value of time, and
c. Difference in lifestyle and habit.

However, we need to conduct further study and analysis to prove these Possibilities. The model yielded by this study might have some weak points here and there, but this study also yields some important point on its part of way of learning. The model obtained might be not accurate enough to picture and predict the behavior of the study locations. The same approach can be done by using larger and varied data samples in order to achieve better results.

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BIOGRAPHY

Rani Nurcharissa was born in Bandung, the capital city of West Java, Indonesia on June 5, 1983. She finished her undergraduate study in Bandung Institute of Technology in 2005 with Bachelor Degree in Civil Engineering. Her final project concerned on evaluation of highway condition with ranking analysis using Analytical Hierarchy Process (AHP). Three months after graduation, she had received the AUN/SEED-Net scholarship from JICA, which enabled her to continue her study to Master's Degree at Chulalongkorn University, Thailand. She focused to continue her work on Transportation Engineering under Civil Engineering Department. Upon graduation, she wishes to finish her study then returning to her home country to work in related field.

Appendices

Chulalongkorn University
Questionnaire (English)

This questionnaire is about master's thesis of Transportation Engineering Program at Chulalongkorn University. The purpose of this study is to get the behavior of drivers related to the availability of Traveler Information and risk taking behavior related to travel time variability as well.

Information will be used for academic purposes only. Thank You.

Section 1 Personal Characteristics
Please tell us about you personal characteristics by ticking (√) the box for the answer that fits you best.

1. Are you:
   ☐ Male ☐ Female

2. Please select your age group:
   ☐ Under 25 ☐ 25 – 35 ☐ 35 – 45 ☐ 45 – 50 ☐ Over 50

3. How much your income per month (in Thai Baht, THB):
   ☐ < 10,000 ☐ 10,001 – 15,000 ☐ 15,001 – 20,000 ☐ 20,001 – 30,000 ☐ > 30,000

Section 2 Travel Characteristics
In these set of questions, we would like you to describe briefly about your daily work trip from home to work/school place.

4. When is your beginning of work/school hour? : ______ a.m. Is it flexible? ☐ Yes ☐ No
   When is your end of work/school hour? : ________ p.m. Is it flexible? ☐ Yes ☐ No

5. Please tell me about your daily trips from home to your work place/school and vice versa (normal travel time):
   Morning Trip:
   Distance = _____ km,
   Travel time = ____ hour ____ minutes.
   Afternoon Trip:
   Distance = _____ km,
   Travel time = ____ hour ____ minutes.

6. Please state the number of days in a month that you experienced travel time:

	Morning	Afternoon
a. Up to 15 minutes longer than normal drive	☐ days	☐ days
b. 15 - 30 longer than normal drive	☐ days	☐ days
c. 30 min – 1 hour longer than normal drive	☐ days	☐ days
d. More than 1 hour longer than normal drive	☐ days	☐ days

7. Have you ever used another route (alternate route) beside your usual route? ***(if your answer in NO, please go straight to question no.11)***

☐ Yes ☐ No

8. How familiar are you on your alternate route?

☐ Very familiar ☐ Familiar ☐ Average ☐ Strange ☐ Very strange

9. How frequent do you use the alternate route during your daily;

<u>Morning trip (home to school/work)</u>

☐ 1-2 times/week ☐ 1-2 times/month ☐ Less than 5 times/year ☐ Never

<u>Afternoon trip (school/work to home)</u>

☐ 1-2 times/week ☐ 1-2 times/month ☐ Less than 5 times/year ☐ Never

10. Are you using the same alternate route for both trips?

☐ Yes ☐ No

11. What is your travel time tolerance before you decide to detour?

	Definitely Stay	Probably Stay	Can not say	Probably detour	Definitely detour
a. 5 minutes longer than your usual travel time	☐	☐	☐	☐	☐
b. 10 minutes longer than your usual travel time	☐	☐	☐	☐	☐
c. 15 minutes longer than your usual travel time	☐	☐	☐	☐	☐
d. 20 minutes longer than your usual travel time	☐	☐	☐	☐	☐
e. More than 20 minutes longer	☐	☐	☐	☐	☐

12. What is the reason that makes you to take the other route? (can tick more than one)

<u>Morning:</u>
- ☐ Accident in usual route
- ☐ Congestion avoidance
- ☐ Pick up/drop off people
- ☐ Stop at other destination before going to work
- ☐ Others ______________

<u>Afternoon:</u>
- ☐ Accident in usual route
- ☐ Congestion avoidance
- ☐ Pick up/drop off people
- ☐ Stop at other destination before going home
- ☐ Others ______________

13. How do you normally learn about congestion (delay)?

☐ By observing ☐ Through traffic report ☐ Both of them

☐ Others, please specify ___________________

14. My current traffic information source is/are (can choose more than one):

☐ Radio ☐ Television ☐ VMS

☐ Internet ☐ Newspaper ☐ In-vehicle Device

☐ Phone Call Service ☐ Personal Knowledge ☐ Intelligent Sign-board

☐ Others, please specify ___________________

Section 3 Variable Message Sign (VMS)

VMS is a traffic information service installed in the side or over the road to display real-time traffic information such as congestion ahead, incident reports, construction works, or even suggestion to detour. This kind of device is quite familiar for major cities drivers. *One point that can be highlighted from this service is; the information given is common, general, and free for all drivers in the same direction*.

Figure 1. Variable Message Sign

15. Do you notice any VMS on your regular route to/from work/school?

☐ Yes ☐ No

16. Do you feel that these kinds of traffic information VMS are useful?

	Very useful	Quite useful	Can not say	Quite useless	Very useless
• Accident ahead	☐	☐	☐	☐	☐
• Travel time = xx minute	☐	☐	☐	☐	☐
• Heavy/low congestion ahead	☐	☐	☐	☐	☐
• Suggestion to take other route	☐	☐	☐	☐	☐
• Others, ___________________	☐	☐	☐	☐	☐

17. Speaking of travel time information by VMS, do you feel that information is accurate enough?

☐ Definitely accurate ☐ Accurate ☐ Average
☐ Somewhat inaccurate ☐ Definitely inaccurate

18. Comparing VMS information and your experience, which one that you likely to believe?

☐ Experience ☐ More likely to experience ☐ 50-50
☐ More likely to VMS ☐ VMS

19. Suppose that you are in your journey to home, and then you see delay information on VMS. If you decide to respond after getting the information, what would you like to do (rather than stay in your regular route)

☐ Stay in the same route ☐ Stop on the way ☐ Others, _______________
☐ Change to your alternate route ☐ Visit any place before arriving home

Section 4 In-vehicle Travel Information Service

Introduction

In vehicle device is a device that gives you various updated en-route traffic information or related information that you need. You need to buy the device and subscribe to the provider for the service with a specific price. It is installed on your vehicle's dashboard, and *the information given to you are detail and private kind of information (you do not share the information with the public like in VMS information)*.

Figure 2. In-vehicle Device

In this section we would like to know your travel behavior influenced by traveler information, particularly by In-vehicle Device.

20. We list every implemented and possible-to-implement feature in this device. In your opinion, how important are they in determining your travel decision?

	Very useful	Quite useful	Can not say	Quite useless	Very useless
• Accident info	☐	☐	☐	☐	☐
• Travel Time delay	☐	☐	☐	☐	☐
• Congestion level	☐	☐	☐	☐	☐
• Route guidance	☐	☐	☐	☐	☐
• Alternate route(s)	☐	☐	☐	☐	☐
• Parking lot information	☐	☐	☐	☐	☐
• Interesting places info	☐	☐	☐	☐	☐
• Potential alternative destination	☐	☐	☐	☐	☐
• Weather reports	☐	☐	☐	☐	☐
• Others ______________	☐	☐	☐	☐	☐

21. Comparing in-vehicle device (IVD) information and your experience, which one that you likely to believe?

☐ Experience ☐ More likely to experience ☐ 50-50

☐ More likely to IVD ☐ IVD (In-Vehicle Device)

Section 5 Intelligent Sign Board

Introduction

Intelligent sign board is a device installed id some major intersections in Bangkok to inform drivers about the level of congestion in some nearby routes. It informs the traffic condition by associating the level of congestions with colors; green, yellow/orange, and red. The route with green color means the level of congestion is the lowest, while red means the densest.

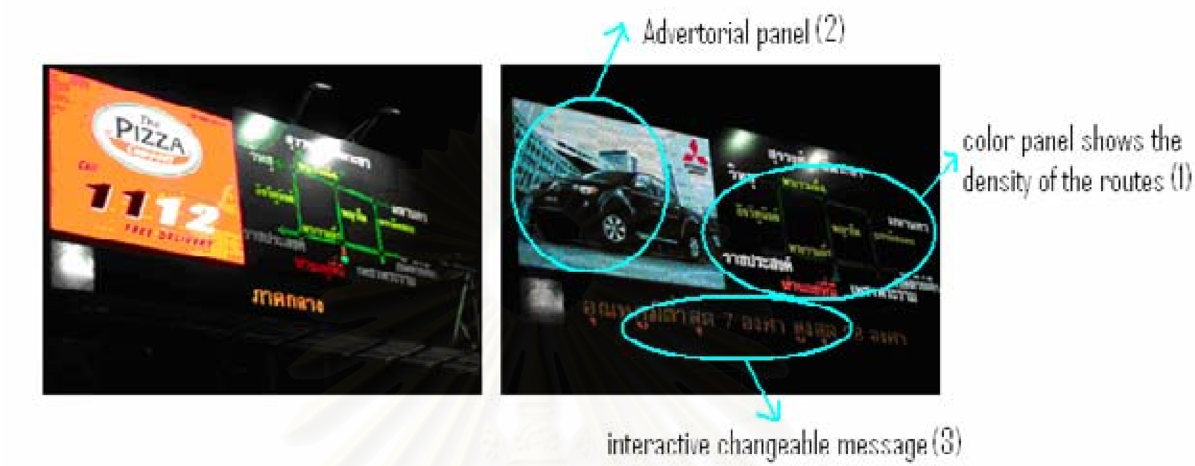

Figure 3. Intelligent Sign-Board

In this section we would like to know your travel behavior influenced by traveler information, particularly by Intelligent Sign Board.

22. Do you notice any intelligent sign board on your regular route to/from work place?
    - Morning trip: ☐ Yes ☐ No
    - Afternoon trip: ☐ Yes ☐ No

23. Do you feel that the information is useful and accurate?
    - ☐ Accurate and useful ☐ Accurate but useless ☐ Average
    - ☐ Inaccurate but useful ☐ Inaccurate and useless

24. Comparing ISB information and your experience, which one that you likely to believe?
    - ☐ Experience ☐ More likely to experience ☐ 50-50
    - ☐ More likely to ISB ☐ ISB (Intelligent Sign Board)

25. We list every implemented and possible-to-implement feature in this device. In your opinion, how important are they in determining your travel decision?

	Very useful	Quite useful	Can not say	Quite useless	Very useless
• Real time traffic condition display on panel (3)	☐	☐	☐	☐	☐
• Interactive changeable traffic messages on panel (2)	☐	☐	☐	☐	☐
• Live traffic report on panel (3)	☐	☐	☐	☐	☐
• Others ____________________	☐	☐	☐	☐	☐

Section 6: Hypothetical Situation

Introduction:

In this section, we would like to know your risk taking behavior on two routes from your home to your work under specific conditions.

Suppose you are on the way to your work in your usual route. Then halfway of the journey, you see information saying that there is an unexpected congestion ahead. You do not have any idea how severe and how long it will take time to be back to normal. You only have a possibility to change into your alternate route with some travel time probabilities associated (this kind of information is based on your experience).

The question is: What would you like to do then? Would you prefer staying in the usual route to diverting into another route?

There are no right or wrong answer, please tick in the box that represents your action then. Thank you for participated in this survey.

Regular Route	Alternate Route	Potential Action
Travel Time: 27 minutes 4 days/week 35 minutes 3 days/week Cost = 0 baht	Travel Time: 27 minutes 4 days/week 35 minutes 3 days/week Cost = 0 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 22 minutes 4 days/week 40 minutes 3 days/week Cost = 0 baht	Travel Time: 25 minutes 3 days/week 43 minutes 4 days/week Cost = 20 Baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 21 minutes 5 days/week 54 minutes 2 days/week Cost = 0 baht	Travel Time: 16 minutes 2 days/week 49 minutes 5 days/week Cost = 40 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 12 minutes 2 days/week 44 minutes 5 days/week Cost = 0 baht	Travel Time: 22 minutes 4 days/week 40 minutes 3 days/week Cost = 0 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 34 minutes 2 days/week 42 minutes 5 days/week Cost = 0 baht	Travel Time: 32 minutes 4 days/week 50 minutes 3 days/week Cost = 40 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Chulalongkorn University
Questionnaire (English)

This questionnaire is about master's thesis of Transportation Engineering Program at Chulalongkorn University. The purpose of this study is to get the behavior of drivers related to the availability of Traveler Information and risk taking behavior related to travel time variability as well.

Information will be used for academic purposes only. Thank You.

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   ☐ Male ☐ Female

2. Please select your age group:
   ☐ Under 25 ☐ 25 – 35 ☐ 35 – 45 ☐ 45 – 50 ☐ Over 50

3. How much your income per month (in Thai Baht, THB):
   ☐ < 10,000 ☐ 10,001 – 15,000 ☐ 15,001 – 20,000 ☐ 20,001 – 30,000 ☐ > 30,000

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In these set of questions, we would like you to describe briefly about your daily work trip from home to work/school place.

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5. Please tell me about your daily trips from home to your work place/school and vice versa (normal travel time):

   Morning Trip:
   Distance = _____ km,
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   Afternoon Trip:
   Distance = _____ km,
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6. Please state the number of days in a month that you experienced travel time:

	Morning	Afternoon
a. Up to 15 minutes longer than normal drive	☐ days	☐ days
b. 15 - 30 longer than normal drive	☐ days	☐ days
c. 30 min – 1 hour longer than normal drive	☐ days	☐ days
d. More than 1 hour longer than normal drive	☐ days	☐ days

7. Have you ever used another route (alternate route) beside your usual route? ***(if your answer in NO, please go straight to question no.11)***

☐ Yes ☐ No

8. How familiar are you on your alternate route?

☐ Very familiar ☐ Familiar ☐ Average ☐ Strange ☐ Very strange

9. How frequent do you use the alternate route during your daily;

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☐ Yes ☐ No

11. What is your travel time tolerance before you decide to detour?

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f. 10 minutes longer than your usual travel time	☐	☐	☐	☐	☐
g. 15 minutes longer than your usual travel time	☐	☐	☐	☐	☐
h. 20 minutes longer than your usual travel time	☐	☐	☐	☐	☐
i. More than 20 minutes longer	☐	☐	☐	☐	☐

12. What is the reason that makes you to take the other route? (can tick more than one)

<u>Morning:</u>
- ☐ Accident in usual route
- ☐ Congestion avoidance
- ☐ Pick up/drop off people
- ☐ Stop at other destination before going to work
- ☐ Others ______________

<u>Afternoon:</u>
- ☐ Accident in usual route
- ☐ Congestion avoidance
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13. How do you normally learn about congestion (delay)?

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14. My current traffic information source is/are (can choose more than one):

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☐ Phone Call Service ☐ Personal Knowledge ☐ Intelligent Sign-board

☐ Others, please specify ___________________

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    - ☐ Yes
    - ☐ No

16. Do you feel that these kinds of traffic information VMS are useful?

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• Travel time = xx minute	☐	☐	☐	☐	☐
• Heavy/low congestion ahead	☐	☐	☐	☐	☐
• Suggestion to take other route	☐	☐	☐	☐	☐
• Others, ____________________	☐	☐	☐	☐	☐

17. Speaking of travel time information by VMS, do you feel that information is accurate enough?
    - ☐ Definitely accurate
    - ☐ Accurate
    - ☐ Average
    - ☐ Somewhat inaccurate
    - ☐ Definitely inaccurate

18. Comparing VMS information and your experience, which one that you likely to believe?
    - ☐ Experience
    - ☐ More likely to experience
    - ☐ 50-50
    - ☐ More likely to VMS
    - ☐ VMS

19. Suppose that you are in your journey to home, and then you see delay information on VMS. If you decide to respond after getting the information, what would you like to do (rather than stay in your regular route)
    - ☐ Stay in the same route
    - ☐ Stop on the way
    - ☐ Others, _______________
    - ☐ Change to your alternate route
    - ☐ Visit any place before arriving home

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Introduction

In vehicle device is a device that gives you various updated en-route traffic information or related information that you need. You need to buy the device and subscribe to the provider for the service with a specific price. It is installed on your vehicle's dashboard, and *the information given to you are detail and private kind of information (you do not share the information with the public like in VMS information)*.

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In this section we would like to know your travel behavior influenced by traveler information, particularly by In-vehicle Device.

20. We list every implemented and possible-to-implement feature in this device. In your opinion, how important are they in determining your travel decision?

	Very useful	Quite useful	Can not say	Quite useless	Very useless
• Accident info	☐	☐	☐	☐	☐
• Travel Time delay	☐	☐	☐	☐	☐
• Congestion level	☐	☐	☐	☐	☐
• Route guidance	☐	☐	☐	☐	☐
• Alternate route(s)	☐	☐	☐	☐	☐
• Parking lot information	☐	☐	☐	☐	☐
• Interesting places info	☐	☐	☐	☐	☐
• Potential alternative destination	☐	☐	☐	☐	☐
• Weather reports	☐	☐	☐	☐	☐
• Others _______________	☐	☐	☐	☐	☐

21. Comparing in-vehicle device (IVD) information and your experience, which one that you likely to believe?

☐ Experience ☐ More likely to experience ☐ 50-50
☐ More likely to IVD ☐ IVD (In-Vehicle Device)

Section 5 Intelligent Sign Board

Introduction

Intelligent sign board is a device installed id some major intersections in Bangkok to inform drivers about the level of congestion in some nearby routes. It informs the traffic condition by associating the level of congestions with colors; green, yellow/orange, and red. The route with green color means the level of congestion is the lowest, while red means the densest.

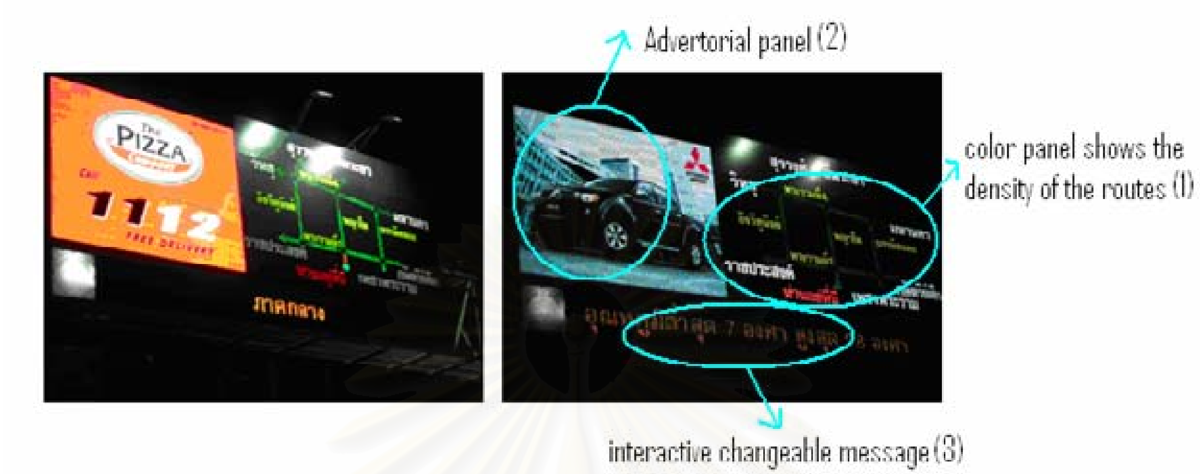

Figure 3. Intelligent Sign-Board

In this section we would like to know your travel behavior influenced by traveler information, particularly by Intelligent Sign Board.

22. Do you notice any intelligent sign board on your regular route to/from work place?

Morning trip:	☐ Yes	☐ No
Afternoon trip:	☐ Yes	☐ No

23. Do you feel that the information is useful and accurate?

☐ Accurate and useful	☐ Accurate but useless	☐ Average
☐ Inaccurate but useful	☐ Inaccurate and useless	

24. Comparing ISB information and your experience, which one that you likely to believe?

☐ Experience	☐ More likely to experience	☐ 50-50
☐ More likely to ISB	☐ ISB (Intelligent Sign Board)	

25. We list every implemented and possible-to-implement feature in this device. In your opinion, how important are they in determining your travel decision?

	Very useful	Quite useful	Can not say	Quite useless	Very useless
• Real time traffic condition display on panel (3)	☐	☐	☐	☐	☐
• Interactive changeable traffic messages on panel (2)	☐	☐	☐	☐	☐
• Live traffic report on panel (3)	☐	☐	☐	☐	☐
• Others ______________________	☐	☐	☐	☐	☐

Section 6: Hypothetical Situation

Introduction:

In this section, we would like to know your risk taking behavior on two routes from your home to your work under specific conditions.

Suppose you are on the way to your work in your usual route. Then halfway of the journey, you see information saying that there is an unexpected congestion ahead. You do not have any idea how severe and how long it will take time to be back to normal. You only have a possibility to change into your alternate route with some travel time probabilities associated (this kind of information is based on your experience).

The question is: What would you like to do then? Would you prefer staying in the usual route to diverting into another route?

There are no right or wrong answer, please tick in the box that represents your action then. Thank you for participated in this survey.

Regular Route	Alternate Route	Potential Action
Travel Time: 27 minutes 4 days/week 35 minutes 3 days/week Cost = 0 baht	Travel Time: 27 minutes 4 days/week 35 minutes 3 days/week Cost = 0 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 32 minutes 4 days/week 40 minutes 3 days/week Cost = 0 baht	Travel Time: 12 minutes 2 days/week 44 minutes 5 days/week Cost = 20 Baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 25 minutes 3 days/week 43 minutes 4 days/week Cost = 0 baht	Travel Time: 34 minutes 2 days/week 42 minutes 5 days/week Cost = 40 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 32 minutes 4 days/week 50 minutes 3 days/week Cost = 0 baht	Travel Time: 21 minutes 5 days/week 54 minutes 2 days/week Cost = 0 baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour

Regular Route	Alternate Route	Potential Action
Travel Time: 16 minutes 2 days/week 49 minutes 5 days/week Cost = 0 baht	Travel Time: 32 minutes 4 days/week 40 minutes 3 days/week Cost = 20 Baht	☐ Definitely Stay ☐ Probably Stay ☐ Can not Say ☐ Probably Detour ☐ Definitely Detour