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Special Issue

Thailand Roadside Safety Strategic Plan

PREFACE

Dear Readers,

Welcome to the third issue of the JOURNAL OF SOCIETY for TRANPORTATION and TRAFFIC STUDIES, a new international peer-reviewed on-line journal. Four issues of the journal will be published annually. This issue covers topics ranging from road design guideline implementation in Thailand, a Euro- Thai collaborative road safety action research project; value of life in non-fatal crashes in Malaysia; speed humps; estimation of CO_2 emission; and effectiveness of transit in university environment, and speed on expressway. The special issue covers the important topic of roadside safety.

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THE PUBLIC TRANSPORTATION PROJECTS TO REDUCE CO2 EMISSION FOR CLEAN DEVELOPMENT MECHANISM IN KHON KAEN UNIVERSITY

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Abstract: This research paper proposes the public transportation projects for Clean Development Mechanisms (CDM) to reduce Carbon Dioxide (CO_2) emission in Khon Kaen University (KKU). The proposed transportation projects are 2 scenarios (The substitution of fuel usage of Song Thaew and the replacement of existing Song Thaew by a campus shuttle bus). The CO_2 emission reduction is estimated by following the principle of CDM. This study applied JICA STRADA program, to analyze the existing traffic volume and to estimate the future traffic volume along KKU road network in 2014. The emission factors are applied to calculate the emissions. The emissions of each scenario are compared with those of Baseline scenario, a condition without proposed project, to evaluate the proposed projects. The evaluation results show that both proposed projects for transportation can reduce significantly the CO_2 emission. Hence, the proposed projects would be possibly considered to be implemented for CDM in Khon Kaen University.

Key Words: Clean Development Mechanism (CDM), Public Transportation, Emission Factor, CO_2 , Khon Kaen University

1. INTRODUCTON

Nowadays, the global climate has been turned to bad conditions. It affects to increase the surface temperature of the earth which caused by the human activities such as transportation sector, agriculture sector, industry sector, and etc. Especially, the transportation sector emits the enormous amount of emission. These activities create the Green House Gases (GHG) that effect to human life. The several countries have tried to find out the solution. Therefore, the United

Nations Framework Convention on Climate Change (UNFCCC) had established from the principle that nation members take a responsibility together with the different levels. As this principle, the Kyoto Protocol has been established to decrease GHG emission, especially Carbon Dioxide (CO_2), the most awareness gas among GHG. The Clean Development Mechanism (CDM) is one strategy of Kyoto Protocol that could reduce the CO_2 emission (OTP, 2007).

Thailand is a developing country. The government has continuously developed in transportation projects, especially, highway construction. But it still not response sufficiently to number of vehicles that increases every year. It causes many problems, such as severe congested traffic, higher energy consumption, environmental pollution and etc. These problems become more serious not only in the metropolitan city, like Bangkok, but also in other big regional cities of Thailand, such as Chiang Mai city and Khon Kaen city.

Khon Kaen city is located in the northeastern part of Thailand which has economic growth, being a center of education and provincial of Indochina. From the traffic survey, 68 % of them travels by private vehicle. 15 % of them travel by public vehicles. And. The remainder travels by walking, bicycle and other kinds of vehicles. There is a high number of registered vehicles and its tendency has increased with a rate of 10 % per year (SIRDC, 2007). This high demand of vehicle usage increases the fuel consumption and causes directly to a huge amount of air pollution emission. Therefore, it is necessary to find out the way to lesson this problem. The alternative fuel and public transport are achievable solution.

This study primarily selects Khon Kaen University (KKU) as the representative study area of Khon Kaen city since there is high growth rate of population and development and population, especially number of students. So, there are the peoples traveling in the university more than 40,000 peoples per day, mostly traveling by private vehicles. It causes mostly the problems as same as the problems occurring in the Khon Kaen city (SIRDC, 2007). The KKU has public transport, a modified pickup truck, called “Song Thaew” in Thai, which is managed by the private company. There are three routes servicing through campus, including Number 8 (New), Number 8 (Old) and Number 16 (New). The service route of Song Thaew in KKU is presented in Figure 1. At recently, the Song Thaew is still not widely used by KKU population for traveling inside the university since the service of Song Thaew is not efficiency and effectiveness, e.g. ineffective schedule with unpunctual and long time waiting, unsafe and uncomfortable vehicle etc. Moreover, the service route still not covers the whole area of KKU, particularly the educational zone. Consequently, the private mode, especially motorcycle, still overcome public mode, being the most chosen mode for traveling inside the university (Piphay, C. 2000).

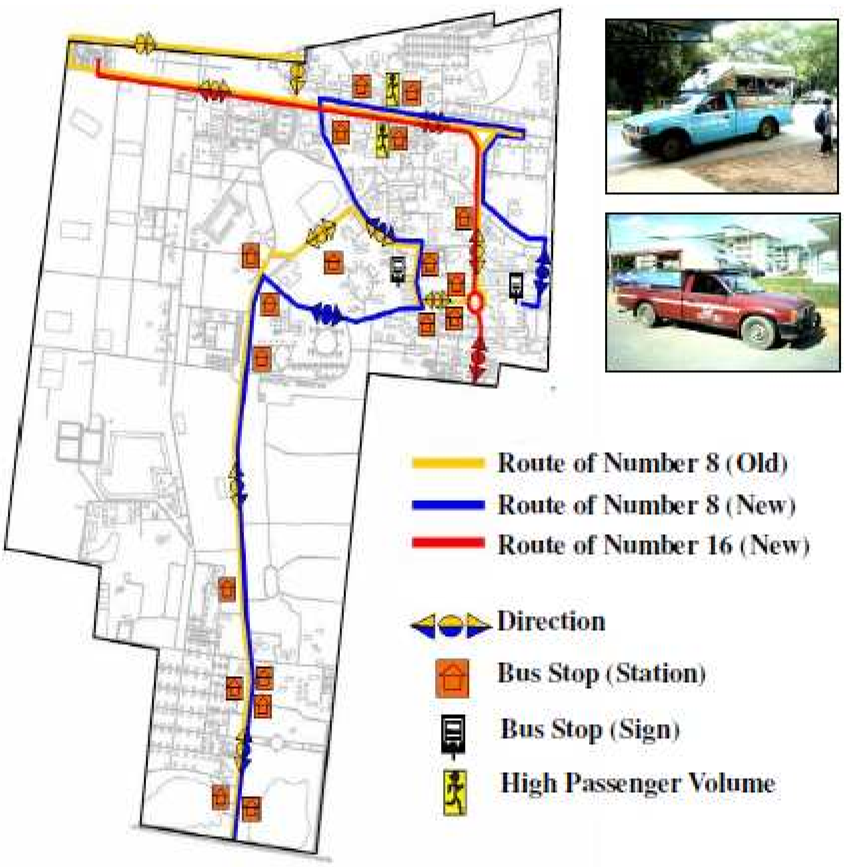

Figure 1. Song Thaew Routes inside Khon Kaen University

2. LITERATURE REVIEW

The authors reviewed many research papers relating with strategy and estimation of carbon dioxide (CO_2) emission reduction as well as application of Urban Transportation Planning to estimate the travel demand. Three research papers related to the study topic are summarized as followings.

Gojash O. (2005) evaluated the replacement of existing fuel with alternative fuels of the bus service companies in Bangkok (Bangkok Mass Transit Authority (BMTA) and private company) by following principle of CDM. This research considered the two case studies. The former study has evaluated the operation of private company with 250 air-conditioned buses using natural compression gas (CNG) The later study has evaluated the operation of BMTA with 3,661 using Bio-diesel (B20, Diesel 80% and Coconut Oil 20%). The evaluation result shows that both case studies could reduce the amount of GHG emission and achieve the cost effectiveness.

Tippichai A. (2007) proposed the alternative fuel for buses of Bangkok Mass Transit Authority. There are totally 3,636 buses with 2,029 air-conditioned buses and 1,594 non-airconditioned buses. The emission of buses was calculated based on the principle of CDM. This research compared the emission of two alternative fuels (Bio-diesel (B10) and natural compression gas (CNG)) with condition without project (Baseline Case). The emission was calculated by the CDM methods, Top-Down and Bottom-Up1 methods. The results show that replacement of existing fuel with B10 has decreased efficiently CO_2 emission rather than CNG.

Daniel M. (2004) studied about an evaluation of transportation policies implementing in Manila, Philippines. There are 8 single policies and 3 combined policies for implementation. The implementing scenarios consist of Motor Vehicle Inspection, Transportation Demand Management, Replacement of 2-Stroke with 4-Stroke Motorcycles for Tricycles, Construction of Bikeways, Expansion of the Metropolitan Railway Network, Diesel Particulate Trap (DPT) for Buses and Jeepneys, Compressed Natural Gas (CNG) for Buses, Coco-methyl ester (CME) for Jeepneys, Combination of all scenarios except railways and switching of two stroke to four stroke tricycles, Combination of all scenarios except railways and Combination of all scenarios. This study applied the 4-step urban transportation planning model to analyze and estimate the exiting and future traffic volume by using JICA STRADA program. The evaluation result reveals that the proposing policies could save about 19% of health medical cost of population. The high effective policies are the motor vehicle Inspection, replacement of 2-stroke with 4-stroke motorcycles for tricycles and expansion of the metropolitan railway network.

3. PUBLIC TRANSPORTATION PROJECTS REDUCING CO_2 EMISSION

This study proposes public transportation projects to reduce the CO_2 emission inside the KKU. The proposed projects are the substitution of fuel usage of Song Thaew, a public Pickup Truck, from Diesel fuel to Compressed Natural Gas (CNG) and the replacement of existing Song Thaew by a campus shuttle bus. The CO_2 emission reduction of each proposed project is estimated by comparing with existing condition without project (Baseline Case) in present year (in year 2007) and 7 years later (in year 2014) following the principle of CDM. The three scenarios are established as follows.

Scenario 0 (Baseline Case): Do Nothing

Scenario 1: Implementing the project of substitution of fuel usage of Song Thaew operating inside KKU from Diesel to Compressed Natural Gas (CNG)

Scenario 2: Implementing the project of replacement of existing Song Thaew by a campus shuttle bus using CNG. This shuttle bus project consists of 4 designed route as shown in Figure 2.

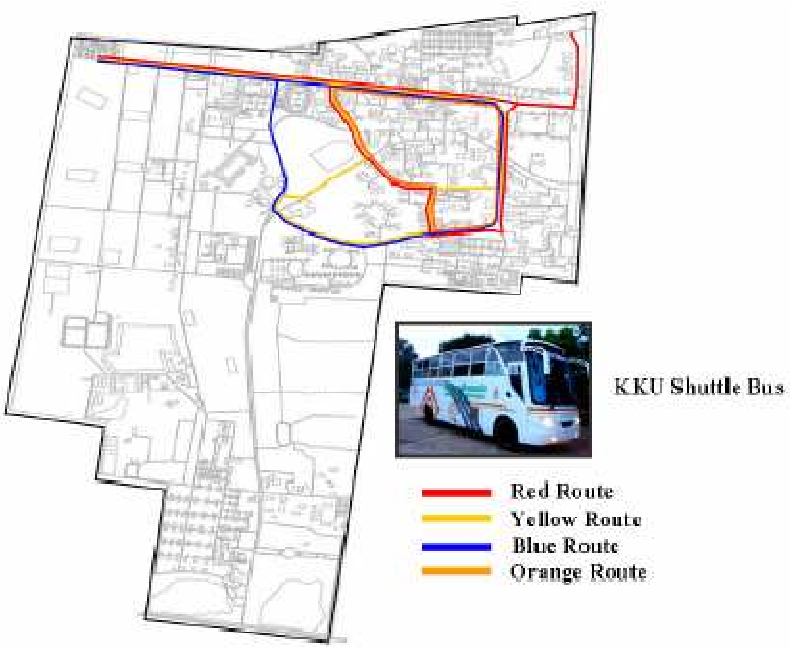

Figure 2. KKU Shuttle Bus Routes

4. METHODOLOGY

This part describes the methodology for calculating Carbon Dioxide (CO_2) emitted from transportation inside Khon Kean University.

4.1 Step of Calculating CO_2 Emission

The authors summarize all steps to calculate CO_2 emission in flow chart for comprehensive understand as shown in Figure 3. This flow chart consists of the first step of data collection, including collecting primary and secondary data. The next step is estimation of traffic volume by 4-step urban transportation planning model using JICA STRADA program, then validating the results (traffic volume and average speed by link). The last steps are calculating CO_2 emission by link and by whole network. The same sequence will be repeat calculated for CO_2 emission in future years.

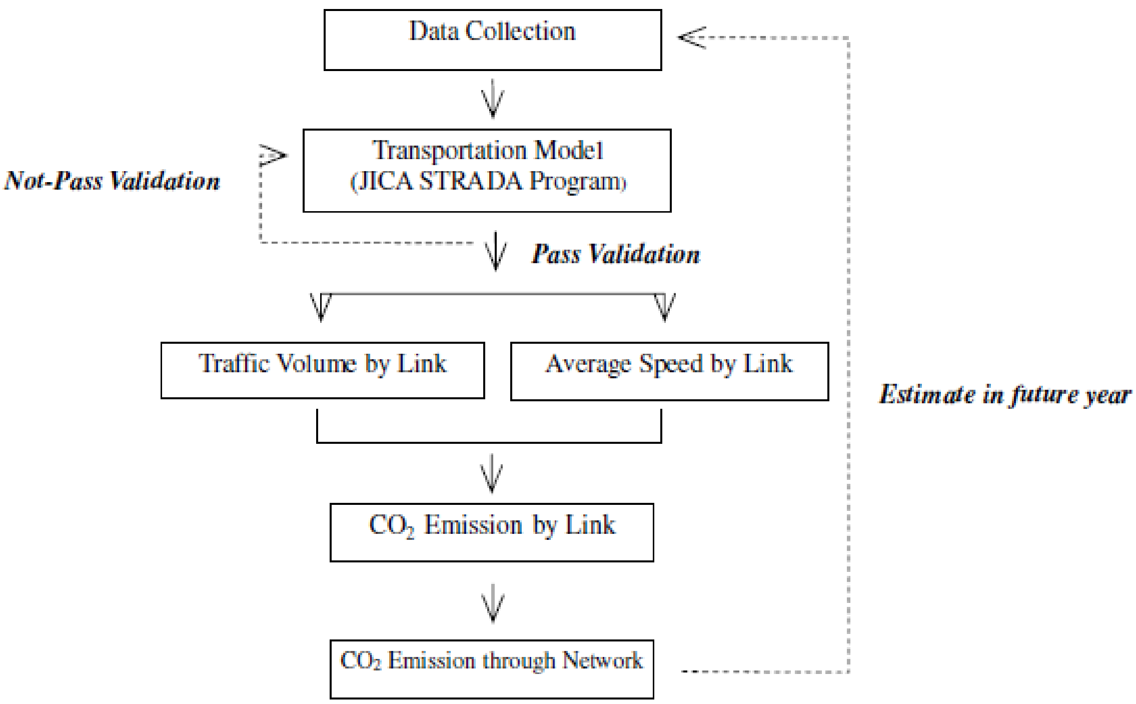

Figure 3. Flow Chart of Calculating CO_2 Emission

4.2 Data Collection

This research collected both primary and secondary data for using in transportation model and CO_2 emission estimation. The collected data is described in detail as follow.

4.2.1 Primary Data

This study has surveyed the service attributes of existing Song Thaew operating through KKU. The surveyed data includes service route, frequency, volume, average speed by link, weight of vehicle, average number of passengers per day, and etc.

4.2.2 Secondary Data

The study has been given the data from several sources. The general data (such as number of population and employment), road network and transportation demand volumes of KKU are given by SIRDC (2007). It surveyed the existing traffic volume on main road by mid block counting. The existing and future travel behaviors (mode choice) of KKU population were surveyed by questionnaire interview. And, the emission data of various speed by each vehicle type is given by MLIT-Japan (2004).

4.3 Calculation of Traffic Volumes along Road Network

This study applied the 4-step urban transportation planning model through using JICA STRADA program to estimate exiting traffic volume (year 2007) and future traffic volume (year 2014) along KKU road network. These 4 steps consist of following steps.

4.3.1 Trip Generation

As the demand model developed by SIRDC (2007), the study area is separated into 52 internal zones and 7 external zones. The linear models has been applied to estimate the trip generation of each zone by trip purposes. The result of trip generation model is displayed by trip purposes as shown in Figure 4.

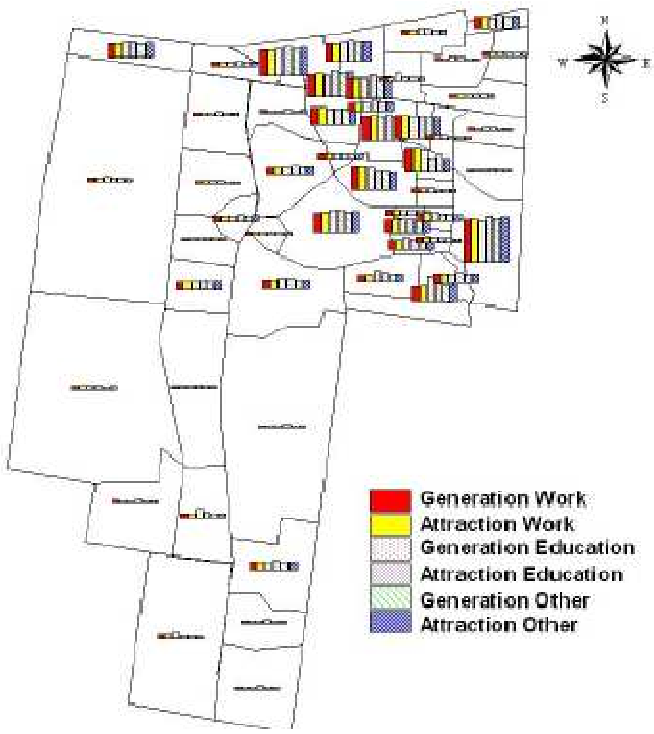

Figure 4. Trip Production and Attraction by Purposes inside KKU

4.3.2 Trip Distribution

The Gravity models has been applied to forecast the trip distribution from zone to zone by trip purpose. The result of trip distribution is presented as shown in Figure 5.

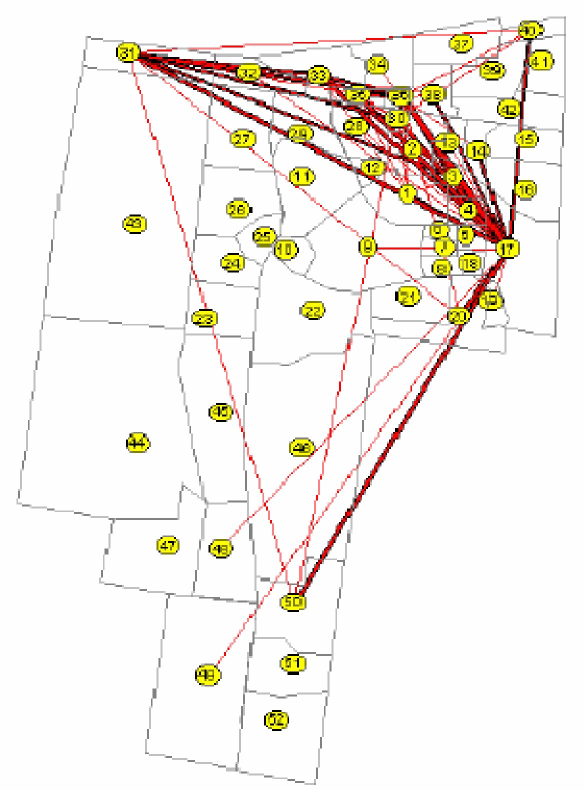

Figure 5. Trip Distribution inside KKU

4.3.3 Modal Split

The Binary Logit model has been applied to split between private and public modes for existing mode choice behavior (Year 2007, Baseline Case). The result of mode split is presented as shown in Figure 6. And, for mode choice behavior in the future (Year 2014), the result from the questionnaire interview would be applied (SIRDC, 2007).

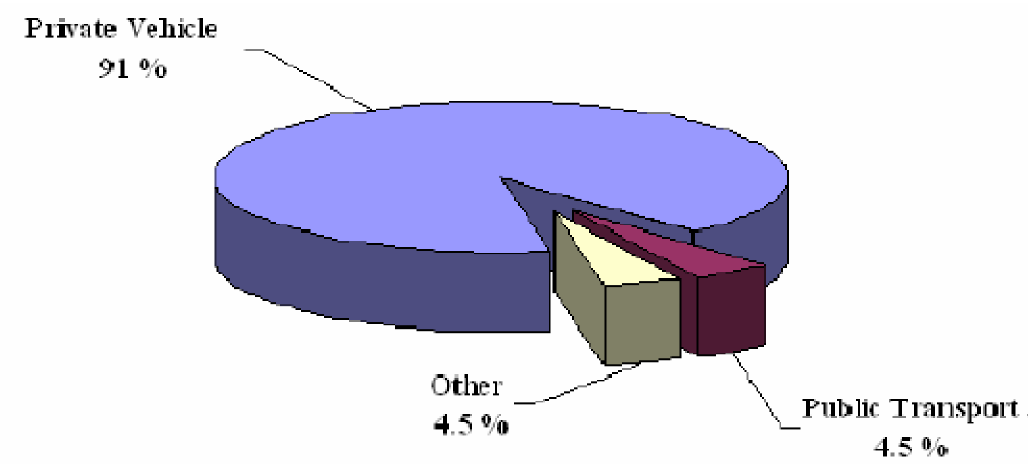

Figure 6. Mode Choice of KKU Population in Year 2007

4.3.4 Traffic Assignment

The User Equilibrium Assignment model has been applied to assign the traffic into the particular road link. The traffic volume along road network resulted by a traffic assignment model is presented in Figure 7.

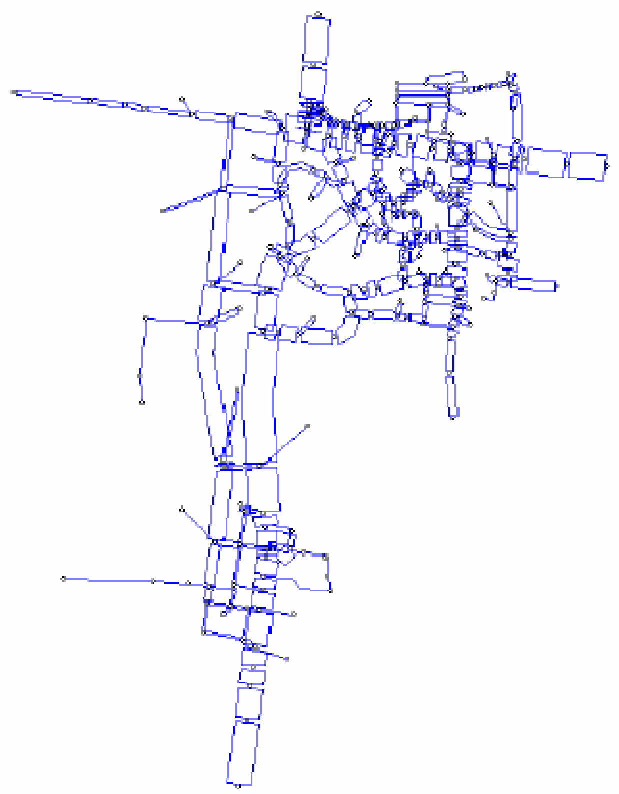

Figure 7. Traffic Volume along KKU Road Network

4.4 Model Validation

After completing a running of a demand model, the traffic volume on each road link resulted from a model has been compared with the real traffic volume by specific link to validate the reliability of the model. The traffic volume inside KKU was surveyed by SIRDC (2007). The result of validation reveals that approximate 80% of traffic volume resulted from a model is matched with the existing traffic volume as shown in Figure 8.

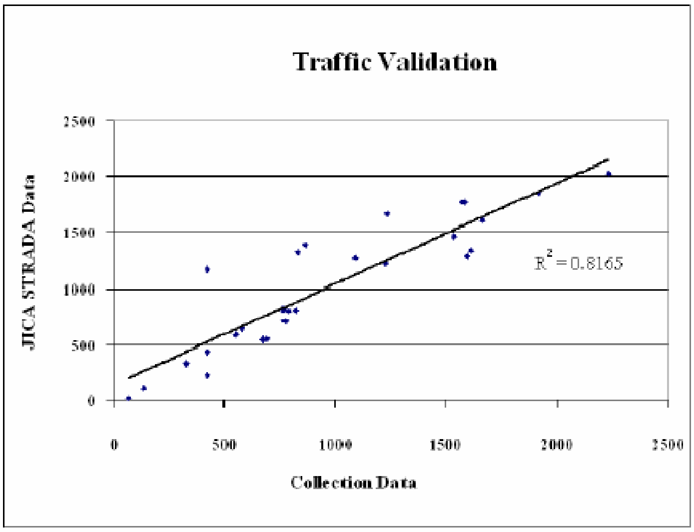

Figure 8. Comparison between Surveyed and Modeled Traffic Volume

4.5 Estimation of CO_2 Emission

After the estimated traffic volumes by link were accepted. There results from traffic assignement model, including traffic volume and average speed by link, would be further applied to estimate the CO_2 emission by link by applying the Equation 1. The Emission factor in the equation are given by the project of MLIT-Japan (2004). This project researched the emission rates of each vehicle type in Bangkok that is similar to the vehicle type used in KKU. Table 1 displays the illustrative result of calculation of CO_2 emission by link in Year 2007 (Based Year).

$$Emission\ of\ Link = \sum_k \sum_i D_k \times T_{ki} \times Ef_{ki} \times WT_i$$

Where

k = Link number

i = Vehicle type (Car, Light Duty Truck, Motorcycle, Truck and Bus)

D_k = Link length (km)

T_{ki} = Traffic volume in link k of vehicle type i (Vehicle)

Ef_{ki} = Amount of CO_2 Emission on link k of vehicle type i (g/km/Ton)

WT_i = Weight of vehicle type i (Ton)

Table 1. Illustrative Results of Calculation of CO_2 Emission by link in Year 2007 (Based Year)

No.	Link Name	Distance (km)	CO2 (Ton/year*)
1	L317	0.52	955.484
2	L309	0.28	407.543
3	L304	0.43	614.056
4	L299	0.10	144.701
5	L288	0.14	180.589
…	…	…	…
199	L336	0.11	33.792
200	L292	0.51	156.670
Total		**38.10**	**22,463.413**

Note: *total 248 weekdays per year

5. RESULTS AND DISCUSSIONS

As the result from emission calculation, the transportation activity inside KKU emits CO_2 about 22,500 Ton-CO_2 in year 2007. The proportion of CO_2 emission by mode is illustrated as shown in Figure 9. It shows that almost emission is emitted by private modes, especially, motorcycle since most of KKU students travel inside KKU by motorcycle.

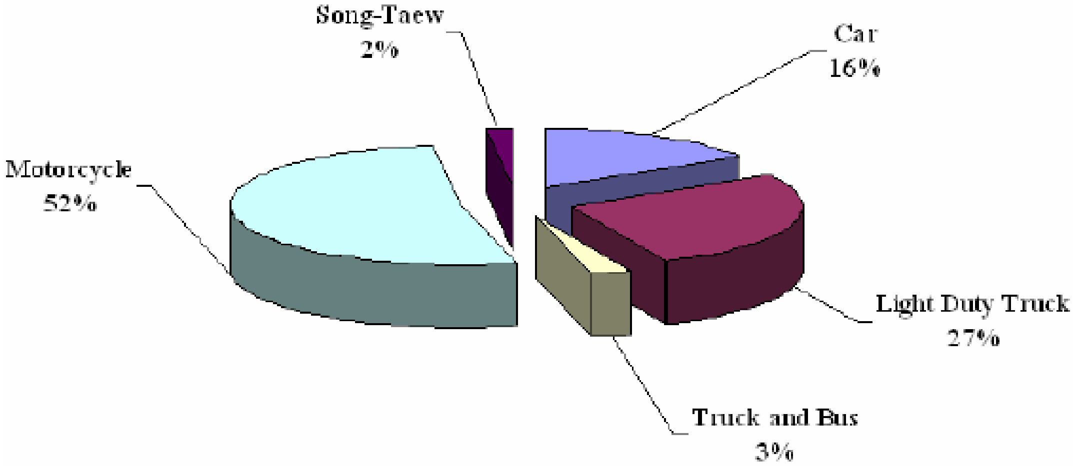

Figure 9. CO_2 Emission by Vehicle Type in Year 2007

Furthermore, if there is no implementation of the project to reduce CO_2 emission in the future. Amount of CO_2 emitted by transportation activity inside KKU will be increased to 31,890 Ton-CO_2 in 7 years later (in year 2014). Since number of KKU population, i.e. students and staffs will increase about 6.9 % and 1.1 % per year respectively (SIRDC, 2007). It therefore causes increasing of traffic volume inside KKU.

However, if there is an implementation of proposed public transportation project in the future whether substitution of fuel usage of Song Thaew operating inside KKU from Diesel to Compressed Natural Gas (CNG) (Scenario 1) or replacement of existing Song Thaew by a campus shuttle bus using CNG (Scenario 2). The CO_2 emission from transportation activity inside KKU in year 2014 will consequently be decreased to 31,670 (Scenario 1) and 30,220 (Scenario 2) Ton-CO_2, respectively as shown in Figure 10. The reduction of CO_2 emission comparing with Baseline Case (Scenario 0) is presented in Table 2.

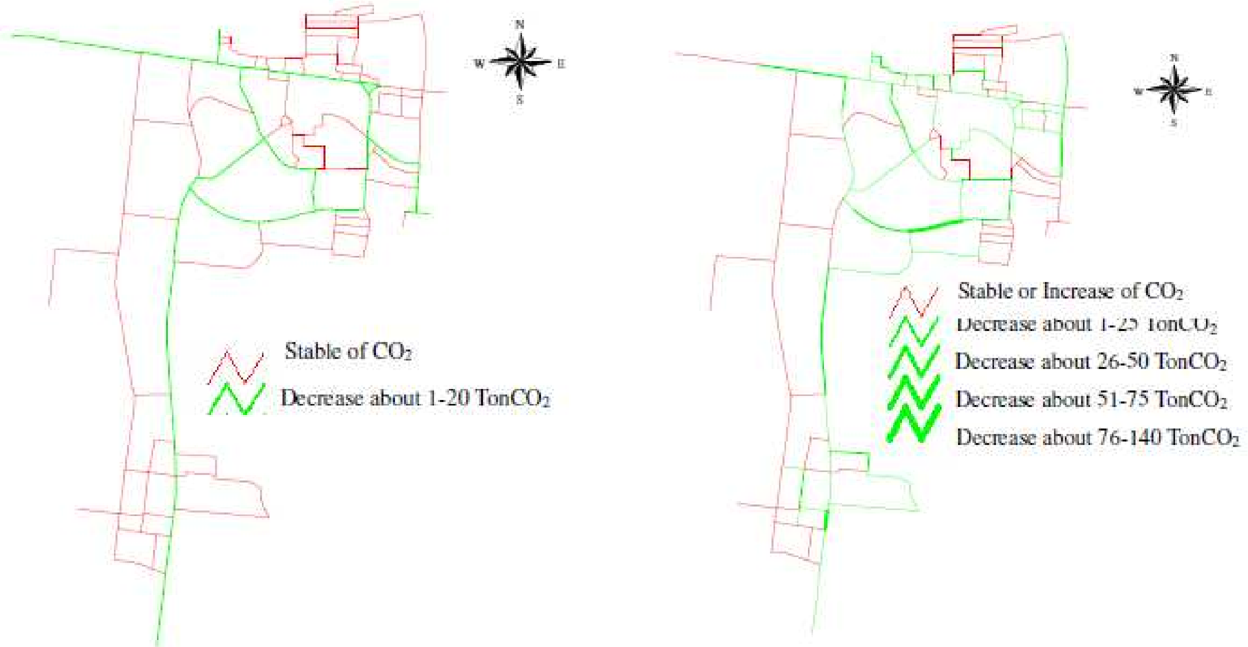

Figure 10. CO_2 Emission along KKU Network by Scenario 1 and Scenario 2

Table 2. CO_2 Emission Reduction Comparing with Baseline Case

Scenario No.	CO_2 Emission in Year 2014 ($TonCO_2$)	CO_2 Emission Reduction in Year 2014 ($TonCO_2$)
0	31,890	-
1	31,670	220
2	30,220	1,670

It can explain that the CO_2 emission reduction from Scenario 1 causes from CNG emitting CO_2 less than Diesel although the proportion selecting Song Thaew for traveling inside KKU is unchanged. On the other hand, the CO_2 emission reduction from Scenario 2 causes from replacing Song Thaew using Diesel with the shuttle bus using CNG and also switching of some private vehicle users to shuttle bus. It results in decreasing of some CO_2 emitted by private vehicle. The CO_2 emission by vehicle types of each scenario is displayed as shown in Figure 11.

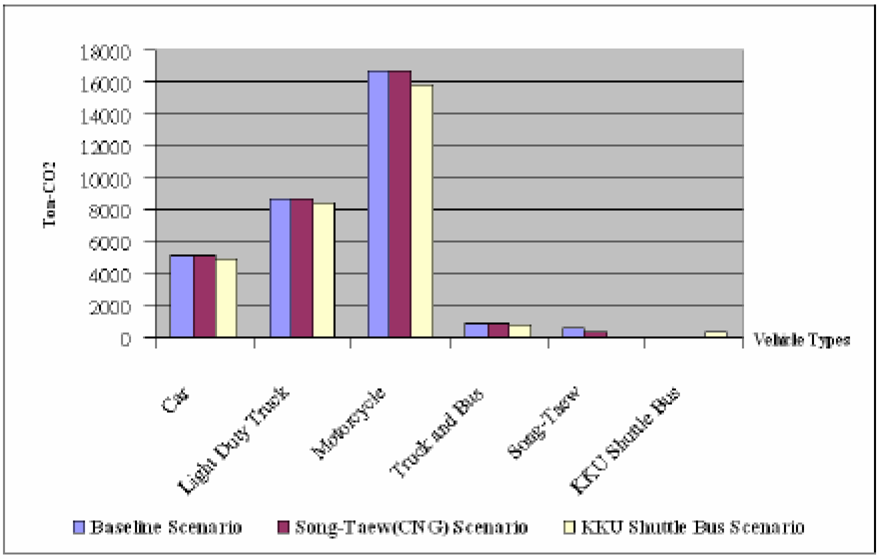

Figure 11. Comparison of CO_2 Emission of each Scenario by Vehicle Type

6. SUMMARY AND RECOMMENDATION

The both proposed public transportation projects can reduce significantly the CO_2 emission in KKU, especially, the project of shuttle bus. Hence, the proposed projects would be possibly considered to be implemented for CDM in Khon Kaen University. As the recommendation for future study, the estimation of CO_2 emission should consider carefully on the load of emitting vehicle because it will achieve more accurate result. The additional policies, such as cover way construction, vehicle ban zone, campaign, and etc., should be considered in order to promote the implementation of shuttle bus project. The more private mode users switching to use shuttle bus the more CO_2 emission reduction.

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HOW EFFECTIVE ARE TRANSIT PRICE INCENTIVES FOR UNIVERSITY STUDENTS WITH AVAILABLE CAR AND URBAN RAIL OPTIONS ? AN EXPERIMENTAL STUDY IN BANGKOK

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Abstract: The objective of this study is to investigate the effectiveness of transit price incentives towards travel mode shift and potential attitudinal changes. An experimental design is conducted based on a sample of university students who are able to commute between home and university either by car or urban rail systems. Two experimental treatments based on different levels of transit price incentives are randomly assigned to the subjects. Travel behavior in terms of frequencies of transit usage is monitored during the four-week intervention, followed by another four-week follow-up study. Statistical analysis results reveal an increase in transit patronage for current captive drivers, even after ceasing the incentives. In terms of psychological changes, we observe that after the temporal structural change via the provision of price incentives, respondents possess better perceptions of perceived behavioral control that taking transit as a commuting mode is easier than before. Policy makers could use lessons learned from this empirical study as an efficient tool to cope with the increase in personal car use in urban cities.

Key Words: Transit price incentives, University students, Travel demand management, Experimental design

2. INTRODUCTON

Nowadays the rapid growth in motorization can be witnessed in many countries. Several concerns have been raised regarding detrimental consequences such as traffic congestion, energy consumption, and air pollution. To cope with these problems, one of the plausible solutions is the application of travel demand management (TDM) or mobility management (MM), which involves strategies that can increase transportation system efficiency and lead to sustainability. Such strategies might include improving transport options, providing incentives for alternative modes, managing parking and land use, or policy and institutional reforms (VTPI, 2007).

Several strategies for increasing transit usage have been examined in literature. Factors influencing commuter's decision to use public transport can be grouped into two aspects, including service quality and price (Giuliano and Hayden, 2005). Transit service quality typically includes such factors as ease-of-use, availability of information, safety, and security. On the other hand, the price aspect may include consideration of transit fare as well as time costs and the foregone comfort and convenience of driving a car. In addition to these aspects, other psychological factors may be also of importance. Examples are attitudes towards travel mode, subjective norm, and perceived behavioral control (Choocharukul and Fujii, 2007).

The focal point of the present study is the application of TDM through a provision of incentives toward a more sustainable urban transportation mode. Specifically, we focus on the effectiveness of price incentives on commuters with the key objective to increase transit usage. From literature review, many transit agencies have investigated the effects due to price incentive strategies. Table 1 collectively summarizes effects from such incentives. Generally, a positive change towards bus patronage can be found but the magnitude of changes is somewhat varied. In terms of controlled experiments, past evidences indicated that price incentive can also effectively lead to an increase in transit ridership, not only from existing public transport users but also from car drivers (see, for example, Katzev and Bachman (1981); Katzev and Bachman (1982); Fujii and Kitamura (2003)). Better attitudes of commuters towards public transport have been noted from these studies. As a result, even after stopping incentive, an increase in public transport users can still be observed to some extent.

In our study, commuters in Bangkok are taken as a case study in a controlled experiment. We consider the urban rail network, which consists of an elevated train system (BTS) operated by Bangkok Mass Transit System Public Company Limited and a subway train system (MRT) operated by Bangkok Metro Public Company Limited. Figure 1 illustrates the rail systems in Bangkok. From commuter’s perspective, the rail network has made the city more accessible. However, given convenient destinations for transit usage, driving may still be a preferable commuting option for many road users.

We propose a hypothesis that appropriate levels of price incentives should be able to induce more transit patronage from existing transit riders or even from current captive drivers. In the long run, we hope that commuting behavior would be continuously changed towards rail transit. Therefore, in setting up an experiment we consider a sample of students from Chulalongkorn University whose residential location can be easily accessed to train stations. There are two primary reasons to justify this experiment. First, both BTS and MRT lines are located within the walking distance of the campus (i.e. Siam station on BTS line and Sam Yan station on MRT line). Still, many students prefer driving even though on-campus parking spaces are quite limited and often students have to take their own risks parking illegally outside the campus. Secondly, all of the studies in the aforementioned literature were conducted in Western countries, with the exception for Fujii &

Kitamura (2003). Most of them examined the effects of price incentives particularly on bus services, while similar research on rail transit system is quite limited. Thus, there remains a research gap for this study to investigate the possibility of changing driving behavior of commuters to the rail transit system. Another distinct point of the present study is that we investigate different level of incentives, i.e. free ticket and half price, while other experiments in literature investigated only the effectiveness of a level of incentive. Under this circumstance, the appropriate level of incentive to change subjects' behavior can be further investigated.

Table 1. Summary of Effectiveness due to Price Incentives

Study	Institute/Location	Starting Year	Types of Price Incentives	Effectiveness
TRB (2003)	Chapel Hill Transit in North Carolina	2001	Free ride on bus services	54 percent increase in bus patronage after one year
TRB (2003)	Maryland Mass Transit in Maryland	1996	Fare structure changed from distance-based ($1.25-$2.25) to a fixed fare of $1.35 and provide daily pass for $3	6.3 percent increase in bus patronage after 6 months and 11 percent after three years
Brown et al. (2003)	Santa Monica Big Blue Bus in University of California, Los Angeles	2000	Free ride on bus services for a fee of $30 per year	56 percent increase in bus patronage and 20 percent reduction in campus car users
Mayer and Beimborn (1996)	Milwaukee County Transit System in University of Wisconsin, Milwaukee	1994	Free ride on bus services for university students	35 percent increase in bus patronage
Witte et al. (2005)	Brussels' Transport Company in Flemish colleges and universities in Brussels	2003	Free ride on public transport services for university students	17.6 percent increase in rail transit patronage and 13.7 percent increase in bus patronage

The outline of this paper is as follows. The first section outlines the study background. The second section discusses research methodology, including sample selection and design of experiment. Study results based on empirical data and statistical analysis are provided in the third section, followed by the discussion and conclusion of the study.

2. METHODOLOGY

2.1 Sample and Experimental Design

A sample in the present study consists of 53 Chulalongkorn University students, who can commute either by car or by urban rail transit to university. This sample was randomly screened from students in campus by means of intercepting survey during December 2007.

Based on their current commuting travel behavior to the university, two different subject groups are considered: those who always drive (captive riders) and those who drive but sometimes take rail transit.

Figure 1. Bangkok Urban Rail Transit Network (Bangkok Mass Transit System Public Company Limited, 2008)

The participants were collected at several locations on campus such as campus parking garage and several faculties. After the respondent is found to meet the study criteria and agrees to participate in the experiment, he/she will be asked for cell phone number in order for us to keep track of commuting behavior during the study period. Additionally, a questionnaire survey asking travel behavior and psychological factors toward several modes of transportation was conducted. Responses from the survey would complement the observed transit usage frequencies in our analysis. A similar survey was also taken for the samples after the intervention period to investigate any potential changes in attitudes.

For each study group, two experimental treatments based on different levels of transit incentives plus one control group were randomly assigned to the samples. In the control group ("*Control*"), respondents were not given any price incentives; only individualized information regarding travel from university to train stations, along with a leaflet encouraging them to use rail transit, is provided. In the second treatment ("*Free Ride*"), respondents were given a free transit pass and were told to use it only for commuting trips between home and university. The pass was initially valid for a maximum of 10 travels and would be replaced in case the credit is used up. Similar to the second treatment, respondents receiving the third treatment ("*Half Price*") were given a transit pass; however, in this case they were told to pay back once the experiment is completed for the amount of 50 percent of the credit they spent for their commuting trips. All respondents in each study group were specifically asked to use transit pass for their commuting trips between home and university only.

Table 2 summarizes our experimental design, showing the number of experimental units in each treatment group.

Table 2. Experimental Units in Each Treatment

Subject Group	**Current Travel Mode from Home to University**	***Control***	**Treatments**	
			Free Ride	***Half Price***
1	Always drive	11	10	9
2	Drive but sometimes use rail transit	8	8	7

2.2 Study Period

Figure 2 illustrates the experimental plan of this study. The experiment involving different levels of transit price incentives is conducted for 4 weeks during *Intervention* period. The frequency of driving and rail transit usage is recorded on a weekly basis. In order to observe potential changes in travel behavior after incentive is ended, a follow-up survey is continued for another 4 weeks (*Post-Intervention*). During this period, the frequency of driving and rail transit usage is still monitored.

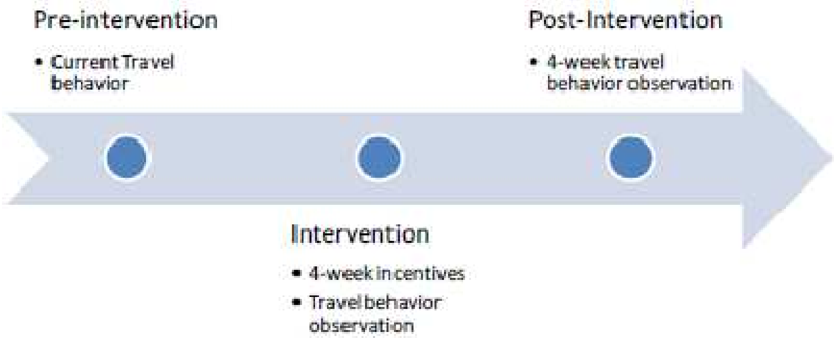


Figure 2. Time Periods during Experiment

3. RESULTS

3.1 Sample Characteristics

Socioeconomic and travel characteristics of the respondents are shown in Table 3. It can be observed that characteristics of the samples in each treatment group are relatively similar. Most of the respondents are between 20 and 21 years old and have monthly income or stipend between 5,000-9,999 THB (approximately US$150 - US$300). In terms of vehicle ownership, respondents on the average possess more than 3 vehicles in their household. From this figure, it is not surprising to find many students driving to campus.

In terms of travel characteristics, it can be noted that the average travel time by car from home to university is in the range of 34 to 39 minutes across each treatment group, while average transit travel time is slightly but not significantly higher than those of car. Access time from home to nearest transit rail station is between 17 and 19 minutes, while the corresponding access cost is between 15-19 THB. From statistical point of view, travel characteristics of the respondents in the *Control*, *Free Ride*, and *Half Price* groups are not significantly different from one another. Thus, it is justifiable to measure the effects of price incentives by directly comparing the frequency of driving and rail transit usage.

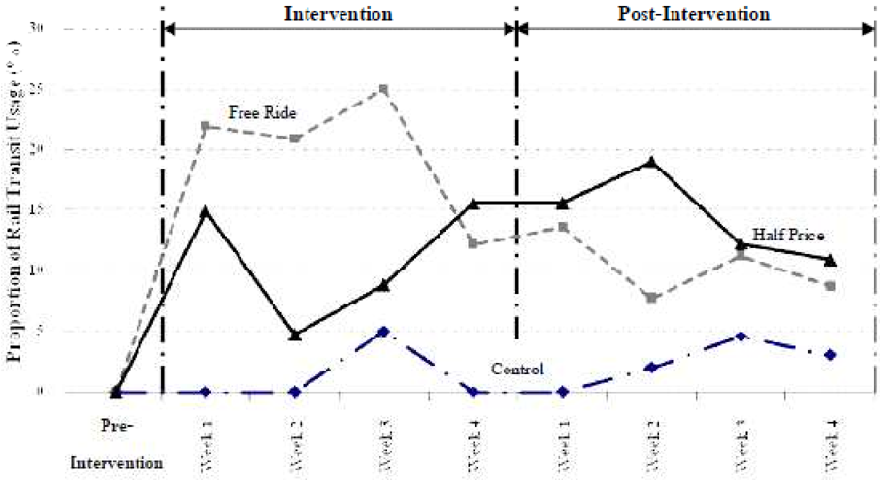
Table 3. Respondent's Descriptive Statistics Classified by Treatments

	Control	***Free Ride***	***Half Price***
Gender Male Female	52.6% 47.4%	44.4% 55.6%	56.3% 43.7%
Respondent's age (years)	21.1 (2.0)	20.8 (1.6)	20.7 (2. 2)
Household vehicle ownership	3.7 (2.1)	3.4 (1.6)	3.3 (1.2)
Income range(THB)			
≤ 5,000	26.3%	22.2%	12.5%
5,000-9,999	47.4%	38.9%	68.9%
10,000-14,999	10.5%	27.8%	12.5%
15,000-19,999	10.5%	5.6%	6.3%
≥ 20,000	5.3%	5.6%	0.0%
Distance from home to university (km)	13.9 (6.6)	15.7 (7.7)	14.6 (9.3)
Travel time from home to university by car (min)	35.9 (16.8)	39.2 (11.3)	33.6 (17.6)
Travel time from home to university by rail transit (min)	40.3 (25.5)	44.2 (16.1)	44.4 (19.2)
Access time to station (min)	17.2 (16.8)	18.9 (11.1)	19.1 (14.2)
Access cost to station (THB)	19.2 (15.3)	17.9 (9.5)	14.5 (9.1)

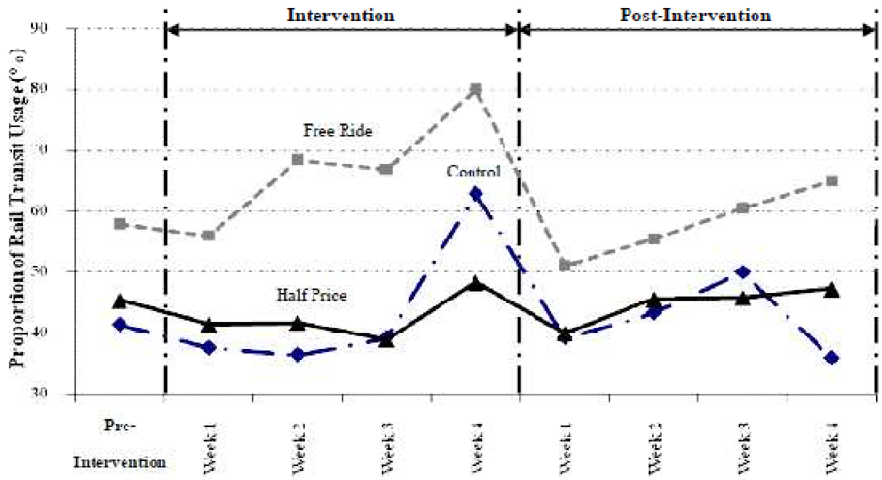
Note: Figures in parentheses denote standard deviations.

3.2 Frequency of Transit Usage during Experiment

The number of days that the subjects commute by car and transit during the experimental period could be used for comparison across treatment groups. However, because each respondent may not commute to campus on a daily basis, it would be more sensible to make comparisons of travel frequency in terms of percentages of the total commuting trips. Figure 3 presents the amount of travel by urban rail transit during the study period for respondents who currently always drive, and for those who drive but sometimes use rail transit, respectively. The observed frequencies classifying by different levels of incentives and study period are tabulated in Table 4.



(a) Respondents who Currently Drive



(b) Respondents who Currently Drive and Sometimes Use Transit

Figure 3. Changes in Rail Transit Frequencies

Table 4. Comparison of Percentage of Transit Usage during Study Periods

		Control	*Free Ride*	*Half Price*
Group 1: Always drive	Pre-Intervention	0.0	0.0	0.0
	Intervention	1.3	20.1	11.1
	Post-Intervention	2.4	10.4	14.5
Group 2: Drive but sometimes use rail transit	Pre-Intervention	41.4	57.9	45.4
	Intervention	44.0	67.8	42.6
	Post-Intervention	42.1	58.0	44.7

From Figure 3(a), it can be observed that price incentive has raised the transit frequencies from zero, i.e. captive driving during pre-intervention period, to some extent. The effects of price incentive for respondent receiving a free transit pass are relatively higher than those receiving half-priced transit pass during the first few weeks after starting intervention. Nevertheless, the trends for *Half Price* and *Free Ride* treatment groups are more or less similar during the post-intervention period, signifying a similar effect among both treatment groups after ending the incentives.

Figure 3(b) presents similar trends for respondents who currently drive but sometimes use transit as a commuting mode to and from university. During the pre-intervention period, the percentage of transit usage of respondents is found to be in the range of 40-60 percent of the total commuting trips. During the intervention period, it is interesting to note that there is a slight surge of transit frequency only for respondents receiving free transit pass, whilst those who have to pay half-priced fare do not exhibit any substantial change in travel mode usage. After intervention, the transit frequencies of all treatment groups drop down to nearly the same level as during the pre-intervention period.

4. ANALYSIS

To evaluate the effectiveness of price incentives, appropriate statistical analysis is required. Price incentive measures would be considered effective when there is a statistical increase in transit ridership during study periods for each treatment group. Thus, two possible analyses can be made, i.e. comparisons across study period and across treatment groups. Since there are a limited number of respondents in this study, normality assumption may not be achieved in all cases. From the Kolmogorov-Smirnov test of normality, we found that transit frequencies for the subject group who always drives do not conform to normality, while the data for respondents who drive but sometimes take transit is found to be normally distributed. Therefore, to test for statistical differences of transit frequencies, we apply Mann-Whitney Utest for the former and student's t-test for the latter. Readers may refer to Neter et al. (1996) and Washington et al. (2003) for further reference on statistical comparisons.

4.1 Transit Frequency Comparison across Study Periods

Table 5 shows statistical comparisons of rail transit frequencies during study periods. For respondents who only drive to campus before the experiment, a free transit pass can effectively induce transit usage ($p<0.05$); however, after we stopped the intervention, the frequencies decline but are not statistically significant comparing with those found in the intervention period. Furthermore, comparison of transit frequencies between pre-intervention and post-intervention for this group shows a significant increase transit patronage ($p<0.10$).

For respondents who always drive and have to pay a half-priced transit fare during the experiment, it can be observed that the frequencies of transit during intervention period are slightly higher than those before intervention. However, no statistical significance is found. The only statistical difference found for the *Half Price* group in this case is between pre- and post-intervention periods, signifying an increase in transit patronage after the cease in price incentive. In terms of respondents who drive but sometimes use rail transit, transit frequencies from three experimental treatments, i.e. *Control*, *Free Ride*, and *Half Price*, do not reveal any statistically significant difference across study periods.

Table 5. Statistical Comparisons of Transit Frequencies across Study Periods

Always drive [1]		Pre-Intervention	Intervention
Control	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.
Free Ride	Intervention	$p < 0.05$	-
	Post-Intervention	$p < 0.10$	n.s.
Half Price	Intervention	n.s.	-
	Post-Intervention	$p < 0.10$	n.s.
Drive but sometimes use rail transit [2]		Pre-Intervention	Intervention
Control	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.
Free Ride	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.
Half Price	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.

Note: n.s. = not statistical significant; p indicates the probability value (p-value).
[1]Based on Mann-Whitney U test; [2]Based on Student's t-test

4.2 Transit Frequency Comparison across Experimental Treatments

Table 6 presents statistical comparisons of rail transit frequencies during each study periods across experimental treatments. For respondents who always drive to university before the experiment, results during the 4-week intervention period show that the *Free Ride* treatment effectively induces more transit patronage than the *Control* group ($p<0.01$). The effectiveness of price incentive during intervention can also be seen by comparing the frequencies of transit usage between *Half Price* and *Control* groups ($p < 0.01$); however, there is no statistical difference in transit frequencies between respondents receiving a free pass and those receiving a 50% off transit pass.

From the observed frequencies of rail transit usage after ending price incentives, the general decreasing trend for the respondents receiving *Free Ride* treatment during the intervention can be observed, as seen in Figure 3. However, no statistical significance is detected between those receiving *Free Ride* and *Half Price* treatments. Yet, these respondents are found to have statistically higher frequencies of transit usage when compared to the *Control* counterpart ($p<0.01$).

In terms of those who drive but sometimes use rail transit to the university, the frequencies of transit usage are not statistically significant for all experimental treatments during the preintervention period. However, when price incentives are introduced, the rail transit usage of respondents in the *Free Ride* treatment is statistically higher than the other two groups ($p<0.05$ and $p<0.10$ compared with *Half Price* and *Control* groups, respectively). Surprisingly, there is no statistical difference in transit usage between those getting a half-fare transit pass and the control counterpart. For the post-intervention period, it is found that transit frequencies are more or less the same across treatment groups and no statistical difference is found.

Table 6. Statistical Comparisons of Transit Frequencies

Always drive [1]		Pre-Intervention	Intervention
Control	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.
Free Ride	Intervention	$p < 0.01$	-
	Post-Intervention	$p < 0.01$	n.s.
Half Price	Intervention	$p < 0.01$	-
	Post-Intervention	$p < 0.01$	n.s.
Drive but sometimes use rail transit [2]		Pre-Intervention	Intervention
Control	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.
Free Ride	Intervention	$p < 0.10$	-
	Post-Intervention	n.s.	$p < 0.05$
Half Price	Intervention	n.s.	-
	Post-Intervention	n.s.	n.s.

Note: n.s. = not statistical significant; p indicates the probability value (p-value).
[1]Based on Mann-Whitney U test; [2]Based on Student's t-test

5. DISCUSSION AND CONCLUSION

This study attempts to promote urban rail public transport by means of price incentives. Experimental study of Chulalongkorn University respondents reveals a promising result that behavior of captive drivers who have options to use rail transit can be changed by introducing them to public transit using price incentive strategies. From our empirical result, it is noteworthy that the increase in transit patronage is observed only for captive drivers regardless of levels of incentives. On the contrary, for respondents who drive but sometimes use rail transit, price incentive does not make any substantial impact on the frequencies regardless of levels of incentives. In fact, statistical comparison shows no difference in transit usage for those who are currently switching between driving and rail transit between preintervention and during intervention periods.

After even the incentive is stopped, an increase in transit usage is found for car-captive respondents in both *Free Ride* and *Half Price* treatments when compared with those in the pre-intervention period. However, these two treatments do not result in any distinction in the amount of transit usage and thus can be regarded as equivalent in terms of the effectiveness in inducing more transit patronage. Therefore, an appropriate pricing strategy for transit operators needs not to be a free pass; only half-priced ticket would have similar impact in terms of the change in transit ridership. For respondents who drive but sometimes take rail transit, we found that price incentive measures do not result in an increase in transit patronage. Hence, it may be concluded that price incentive should be targeted at those who always drive, instead of those who are already switching between two modes.

Results in the present study reveal that when the price incentive is limited to one trip purpose (i.e. commuting trips between home and university in this study), the amount of car travel is reduced while the amount of rail transit increases. The result in this research are in line with findings by Fujii, Garling and Kitamura (2001), where an increase in frequency to use public transport was found only for the drivers who *strongly habitually* (or exclusively) used a car and get to use by the temporary structural change, i.e. freeway closure in that research. This result was caused by the fact that psychological impacts that may support continuous behavioral change was larger for strong habitual drivers than that for the other drivers.

Implications of the findings in this study may be twofold. First, our empirical data indicates that behavioral change to public transport is possible through temporary structural change such as providing transit fare incentives. Therefore, policy makers could use this strategy as one of the TDM measures to convert automobile travel demand to those of public transportation. Secondly, the fact that the differences in psychological variables between preand post-intervention period are statistically significant leads us to another potential transport policy package, which could directly alter road user's perceptions towards rail transit. Such a mobility management strategy that has been proved successful in other countries (see, for example, Fujii and Gärling (2005); Fujii and Taniguchi (2005)) could be promoted for Bangkok's commuters. In terms of future study, as this research collects attitudinal information from the respondents, we intend to investigate potential psychological changes due to price incentives across the experiments. We hope that such an investigation would shed more light on the understanding of mobility management in shifting travel behavior towards a more sustainable transport mode in Bangkok.

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MALAYSIA VALUE OF STATISTICAL LIFE FOR NON-FATAL INJURY IN ROAD ACCIDENT: COMPARISON BETWEEN CA AND CV RESULTS

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Abstract: The acknowledgment on the consequences from road accident had usually credited injuries very briefly. In the effort to provide the best level of road safety to the people, underestimating the setback of road accident injury may lead to insufficient resources allocated to the sector. Hence, this study attempts to estimate the value of non fatal injury due to road accident in Malaysia. This task incorporates the association of cost with Malaysian willingness to pay to reduce the risk of injury. The Value of Statistical Life (VOSL) subjectively estimates people's pain, grief and suffering through a set of Stated Preference questions. This study has adopted the methods of Contingent Valuation and Conjoint Analysis through survey questions. The VOSL estimated from CA gives a range of RM 0.3 million to RM 0.8 million for non-fatal injury which is comparable to CV estimates ranged between RM 0.28 million to RM 0.7 million.

Key Words: Value of Statistical Life, Injury Costing, Willingness to Pay, Conjoint Analysis, Stated Preference

1. INTRODUCTON

The problem caused by road traffic accident had been continuously voiced out by global community since decades ago. The death tolls figuring up to annually 1.2 million people died in road accident from around the world (WHO, 2004) prove the scale of the problem and hence called upon immediate attention and action for solution. At current rate, road accident will expectedly elevate its rank as the world's major disease from 9th place up to 3rd place in the year 2020 which is very soon coming. Apart from death, the rest 20 to 50 million people were left with injuries and inability as the result of road accident every year.

Road accident has been reportedly claiming more lives and victims in developing region such as in Asian countries. A study in 2005 by ADB ASEAN found that approximately 75 000 people were killed as 4.7 million victims were left with injuries due to road accident. In 5 years ahead, it was projected that another 385 000 live lost and 24 million injured people will suffer from the accident. Weighing this to the population of about 580 million people in ASEAN countries, the victims of road accident in the region are enormously in large proportion. On the other hand, WHO (2004) reports that almost 60% of fatal accidents occurring worldwide are contributed from Asian countries even though the region accumulates only 16% of all vehicles in the world. In addition, while developed nations are enjoying 10% reduction in their accident death toll, Asian region is suffering from 40% increase in fatal accidents from 1987 to 1995 alone.

1.1 The Cost of Accident

Unfortunately, merely observing these figures alone is not sufficient to conclude for all consequences and other indirectly affected parties on the event of road accident. Other than ending life and physical injuries, road accident may also affect the family and other people hanging their life on the victims whom was for instance, the income provider for the family. A note by ADB Technical Assistance (2005) pointed out that at household level the impact is almost instantly felt as the result of the death of income earner, losing jobs due to disabilities and cost of medical treatment and property damage. The incapacitated victims will possibly need extra help and care from other people to live their remaining life. In either situation, there are other people who were unintentionally dragged into the course which may cause a continuous and long term consequence of losing productive hours, income and deficiency to manpower and labor sources.

The recognition of different areas inflicted by the problem has signified another important measure of road accident impact at individual, society and national level. Socioeconomic impact of road accident had long been considered by developed countries in their effort to formulate better road safety. European countries like United Kingdom, Australia and Switzerland has been continuously revising and updating their cost valuation of road accident death and injuries. As stated in the guidelines from TRL and GRSP reports (2005), there are two main benefits from costing the accident. Firstly, the total annual accident cost at national level can help the government in resource allocation to road safety sectors. The second use is as a tool in the development of economic appraisal and cost benefit analysis with regards to road safety funding and investment.

Since the fight against road accident requires lots of funding, the need to cost for fatal and non injury by accident in Malaysia is becoming vital. As experienced everywhere around the globe, Malaysia is not shielded from confronting the challenging issues on road safety. The gruesome pictures and figures of death and injury everyday on road accident everyday illustrate the severity of the problem to the nation. Thus, appropriate funding and investment are required to initiate any action plans and intervention programs. As road safety was included as one of the many government sectors in Malaysia, the competition to financing and limited resources is inevitable. Hence, justifying the losses and the possible future savings from accident reduction could be the one proper mechanism to weight the worthiness of granting road safety funds and investments.

In Malaysia, there have been several studies that attempt to estimates the cost of road accidents. The first known valuation exercise using a simplified loss of output costing was undertaken by ESCAP in 1983. Later in 1994, Maradiah made a second attempt using the human capital approach that combine loss of output cost, medical treatment cost, vehicle repair cost, insurance and administrative cost. It is interesting to note that Maradiah had incorporated a certain percentage to reflect the value of pain, grief and suffering. Ex-ante costing using the willingness to pay method was pioneered by Norghani and Mohd Faudzi (2003) in Malaysia.

Initially, the first VOSL study using contingent valuation method was restricted to only young motorcyclists. Subsequent study to estimates the VOSL of motorcyclist fatal and non-fatal injuries was conducted in Seremban municipality (Mohd Faudzi, 2004). A breakthrough on VOSL was made in 2006 when a nationwide valuation exercise was conducted on all road users. However, it is important to note that all these stated preference studies were limited only to the contingent valuation approach. To ascertain the robustness of the estimates, it is important that other valuation approaches be utilized as the value will be the reference to the future cost-benefit analysis (CBA) on road safety related appraisals.

It should be noted that this paper only include the valuation on non-fatal injury taken from a comprehensive study on both fatal and non-fatal injury due to accident. This paper is organized as follows. Section 2 will explain about the methodological part of the study on the design of questionnaire using CA method and the execution of nationwide survey. The result and analysis will be presented in section 3 followed by discussion and conclusion in section 4. Pilot study using CV method will only be discussed as result and comparison in section 4.

2. METHODOLOGY

2.1 Samples and Respondents

The sampling design in used post-stratification sampling where the distributions of sample were stratified according into states and races. For each state the samples were quantified based on district proportion of registered vehicle in the particular state. The initial stage of determining sampling distribution in CA makes use of the comprehensive list of registered vehicles and owners from Malaysian Road Transport Department.

In the attempt to get the insight of representing the true population of Malaysian, this study had cover the whole 13 states of Malaysia including Peninsular Malaysia, Sabah, Sarawak and Federal Territories. The practice is in consideration of the possibility of different level of development and social economic status among different states in Malaysia which may as well contributes to different appreciation level to road safety among the people.

2.2 Questionnaire (CA)

The questionnaire in this study is used as a medium to elicit out people's WTP. The questions prompting on WTP is designed in such a way that the result can be analyzed and interpreted using CA method. Choice experiment technique is employed in the study. Thus, all the attributes are arranged to achieve orthogonal combination between attributes and level of attributes. For every injury category there are two attributes with three levels each. The two attributes are the cost to install for a safety device to the vehicle and the risk reduction after installing the device. Full-factorial design gives 9 profiles selections which are broken down to 3 profiles per set of questionnaire for each injury category. This produces 3 different sets of questionnaire with 3 profiles in each.

The presentation of the choices of selection make used of SP approach by asking people to imagine a hypothetical safety device with certain features that may help reduce their accident risk or injury risk. Other than the cost and risk, other variables are assumed constant. Following the CA design and SP choices, the design therefore separates the questions into four sections as follows:

<u>SECTION A</u>: Introduction

This section explains the aim of this study to respondent and introduces the concept of risk regarding road safety. The questions aim to acknowledge respondent and their family experiences relating to road accident and to assess individual perceptional risk of their own safety regardless of their kin risk.

<u>SECTION B</u>: Selection of safety devices and travel scenarios

The core cause of conducting this study relies on respondent selection of cost trade off in conjunction to their risk reduction. The first part of this section is designed to simulate such user behavior by optioning series of cost and risk reduction alternatives to respondents. To familiarize respondent with the alternatives available, an imaginary situation is presented in which respondents are offered to install a speed controlling device to their vehicle. The characteristics of the device are assumed equal with exception for the monthly installation cost and the efficiency of the device to reduce the base risks. The random pairings of cost and risk reduction are treated as the selection of attribute and alternatives. Three sets of profiles are hence presented in each set of questionnaires.

<u>SECTION C & D</u>: Personal details & Transport ownership and usage information
Demographical background of respondent is monitored through section C. This comprises of age, gender, race, religion, marital status, income and other relevant factors that may influence or describe respondent preference in valuing their life. Section D brings about a quick glance on respondent particulars to licenses, vehicle usage, driving experiences and purpose of transport. Currently the work on valuing monetary losses due to accident in Malaysia is very rare since the advantages of the practice had just recently being discovered. Previous research (Yusof et. Al 2001 and Umar) has come up with the valuation as shown below.

Table 1: The base value to estimates the accident loss

Injury Casualties	Base for Loss Valuation
Death	RM 1.2 Million
Severe Injury	RM 120,000
Slight Injury	RM12,000

Source: Road Safety Department (http://www.jkjr.gov.my/statistik.html)

Table 2 below indicates the estimated the annual monetary loss from death and injury due to road accident in Malaysia utilizing the base values in Table 1. Since currently only the VOSL estimations were briskly studied, it is assumed that the excepted base value has yet to include the other components of the comprehensive accident costs namely the lost output, medical costs, damage costs and the administrative costs of police and insurance.

Table 2: Loss incurred by accident according to injuries and death from year 2001 to 2007

Casualties	2001 (RM) million	2002 (RM) million	2003 (RM) million	2004 (RM) million	2005 (RM) million	2006 (RM) million	2007 (RM) million
DEATH	7,018.80	7,069.20	7,538.40	7,467.60	7,425.60	7,544.40	7,538.40
SEVERE INJURY	1,042.08	1,011.00	1,084.92	1,108.08	1,039.20	1,110.48	1,112.76
SLIGHT INJURY	431.68	422.87	448.87	463.49	377.15	238.61	221.33
TOTAL	8,492.56	8,503.03	9,072.19	9,039.17	8,841.95	8,893.49	8,872.49

Source: Road Safety Department (http://www.jkjr.gov.my/statistik.html)

3. RESULT

3.1 Discarded samples & Demographic profiles

In the end of the survey stage, a total of 3285 respondents were involved in the CA study amounting to 9855 (3285 x 3) samples. This is the result of treating each profile for every injury as distinct samples. Since there are 3 choice profiles for each injury category, thus three samples are attained from a respondent. Out of 9855 samples, 855 samples are excluded inclusive of 717 samples (239 respondents) which failed to properly value their own fatal risk. The rest 138 samples are among 46 respondents who illogically stated their monthly expenses exceeding their monthly incomes. After the cleaning process, a total of exactly 9000 samples were examined in this survey. There were 4578 samples for cars while the remaining 4422 samples are for motorcycle.

Brief examination on selected demographical profile of the samples gives the insight of the age, race, and gender and income distribution. For car, most of the respondent aged between 30 to 40 years with 44% while 49% of the same age group goes for motorcycle. Male respondent dominates gender distribution with 55% for car and 69% for motorcyclist. Distribution of race follow the stratified sampling design with 52% and 73% of the respondent for car and motorcycle respectively are from Malay ethnic. Interestingly, Chinese occupy 38% among car sample but only 16% for motorcycle. Income level for most respondents accumulates around RM 1000 to RM 1500 per month.

Inspection on accident history reveals that on average 90% of the respondent have seen accident and more than half of them were involved in road accident. Assessment on family shows that half of the respondents have at least one of their family members injured in road accident. There are only 8% to 11% of them whom their family member become the victim/s in fatal accident. Most respondent for car considers their fatal risk as 1 to 5 per 100000 populations while for motorcyclist, they perceive their risk as 1 to 10 deaths per 100000 populations.

3.2 Conjoint Analysis

There are 4 models with 2 for car namely CSV (car severe injury) and CSL (car slight injury) and 2 for motorcycle namely MSV (motor severe injury) and MSL (motor slight injury). Since the choices of WTP are in discrete choice presentation, logistic regression analysis is run for the VOSL estimate. The calculation of VOSL make used of the coefficients of cost and risk reduction and the formula in equation (3.9). Logistic regression is more favorable in this study since it includes the interactions in the possibility of respondent selecting and not selecting either alternative. Moreover the binary nature of the choice selection exercise do not allow for the assumption of linear interaction between WTP and risk in linear regression analysis.

Logistic regression on the dependant variables and independent variables gives the VOSL value as for Malaysia and according to states as in table 9. This study proposes the VOSL for each injury involving car drivers as RM 779,896 for severe injury and RM 346,813 for slight injury. Estimates for motorcyclist are RM 508,226 and RM 329,492 for severe injury and slight injury consecutively.

Table 3: VOSL according to injury categories and states (RM)

CAR

STATES	**SEVERE INJURY**	**SLIGHT INJURY**
Johor	**781,741	**353,143
Kedah	*687,870	**318,549
Kelantan	*698,950	329,736
Kuala Lumpur	***844,085	**359,686
Melaka	693,163	308,309
Negri Sembilan	*735,279	*341,687
Pahang	701,444	**365,325
Penang	618,776	310,149
Perak	**776,142	*324,044
Perlis	494,164	201,388
Sabah	**756,693	329,592
Sarawak	*715,676	**326,010
Selangor	***907,632	***404,098
Terengganu	656,065	*353,522
MALAYSIA	***779,896	***346,813

MOTORCYCLE

STATES	SEVERE INJURY	SLIGHT INJURY
Johor	***515,315	***281,036
Kedah	**535,777	**248,549
Kelantan	**514,216	202,449
Kuala Lumpur	*527,291	**306,005
Melaka	453,035	267,481
Negri Sembilan	516,119	258,705
Pahang	509,928	258,654
Penang	618,776	302,241
Perak	*512,320	***282,333
Perlis	494,164	200,000
Sabah	501,662	***330,005
Sarawak	**518,673	***308,277
Selangor	***673,001	306,509
Terengganu	481,897	298,207
MALAYSIA	**508,226	329,492

**significant level at 0.1, **significant level at 0.05, ***significant level at 0.01*

The estimation is extended to different states in Malaysia because each state is distinctive to others in terms of the socioeconomic status, development, industrial sectors and even the road safety condition. The highest VOSL for car was observed at Selangor with CSV costing about RM 907,632 and CSL estimated at RM 404,098. Selangor also quotes highest value of RM 673,001 for MSV whereas Sabah denotes highest with RM 330,005 for MSL by motorcycle. All figures were statistically significant. This is not quite odd since Selangor is among the most developed states in Malaysia and thus may have constituted respondents with higher income level.

3.3 Factors influencing the VOSL

Several variables have been tested to detect for any significant contributions and effects to the VOSL. Linear regression analysis is used to test for the possibility of multicollinearity among the variables. Multicollinearity is the result of the existing interactions between the possible factor variables. Variables with this problem are excluded from the analysis of factor variables. The regression implies that 8 variables which are income, gender, race, age, accident history, vehicle ownership, driving experience and employment background have pass the multicollinearity test and significantly influence the estimates of VOSL.

The examination on the effects of each variable is shown in Appendix A. VOSL increases along with the level of income except for CSL model where the highest value goes to respondent with the lowest income level at below RM 500. According to the result, VOSL of males is higher than females but this variable is only significant to MSV model. As expected, Chinese which is leading in Malaysian economics hierarchy also has the highest VOSL in MSV but in CSL Malay ethnic top the value whereas Chinese have the lowest value. The variable race is not found significant in the other 2 models.

Respondent having the experience of family member/s died from accident make up for higher VOSL in CSL than those with no such experience. For motorcycle, those whom had never seen accident are willing to pay more as can be inspected in MSV however the pattern is reversed in MSL models. Motorcyclists whom had witnessed accident slightly have higher VOSL compared to those with no such experience. However, the MSL model is also inversely affected by respondent's involvement in accident as they give lower value of RM 270,208 while those never being the victim have the VOSL of RM 444,342.

Respondent working in government sectors significantly affected the CSV as they generated higher VOSL than those in private sectors. Variable experience in driving shows positive influence only to CSV model while age is only significant to MSL with the VOSL is higher for older respondent. Both models for car are significantly influenced with vehicle ownership in the way that people in no possession of private vehicle seems to be willing to pay more for their safety as opposed to those already own their vehicles. Respondent with more years of having license are more willing to take higher risk of severe injury in CSV but pay more to reduce slight injury in MSL model. Although the same variable is found significant, the values for CSL and MSV models varies with no observable trend.

The VOSL according to each variable influencing the models are presented in Appendix A. it should also be noticed that all of the influence factors are significant. The coefficient and significance p value for each factors shown in Table 4 are taken from regression analysis:

Table 4: the coefficient and p value for factor variables in each model

VARIABLE COEFFICIENT	**CSV**	**CSL**	**MSV**	**MSL**
	B(**Sig.**)	B(**Sig.**)	B(**Sig.**)	B(**Sig.**)
Income	0.000(**0.000**)	0.000(**0.000**)	0.000(**0.000**)	0.000(**0.000**)
Seen accident	-	-	-0.080(**0.008**)	-0.099(**0.002**)
Age	-	-	-	0.003(**0.001**)
Involved in accident	-	-	-	-.045(**0.010**)
Employer	.025(**0.027**)	-	-	-0.027(**0.030**)
Race	-	0.031(**0.001**)		-0.028(**0.013**)
Risk perception	-0.007**(0.000)**	-0.008**(0.000)**	-0.003**(0.027)**	-
Gender	-	-	0.036**(0.049)**	-
Vehicle ownership	-0.079**(0.025)**	-0.081**(0.003)**	-	-
Family-died	-0.079**(0.005)**	-	-	-
No. of years driving	-0.068**(0.023)**	-	-	-
No. of years held license	-0.016**(0.000)**	-	0.021**(0.000)**	-

3.4 Comparison with valuation by local studies

To date, there exist only 3 studies with the attempt to value the cost of injuries in Malaysia. Studies by Klockner gave the value of RM 14 500 and RM 1 450 while Maradiah gave RM 14 292 and RM 1 087 consecutively for serious and slight injury. The most recent attempt by Faudzi and Norghani (2003) quote the value for all kind of injuries at RM 84 000. All of these studies made use of different methods with the inclusion of several types of cost related to road accident and injury. The VOSL resulted from the pilot study using Contingent Valuation prior to this was quoted at the range of RM 0.54 million to RM 0.7 million for slight injury and RM 0.28 million to RM 0.4 million for severe injury. Apparently, these values are in consistent range with the VOSL from this study.

4. CONCLUSION

The safety of road user is not a mere stuff that can be simply valued and assigned to cost. Thus, proper valuation on road safety should take into account every aspect of people's need and welfare so that the end result could be used as a tool in the decision making at government level. This is to ensure the proper resources, planning, policies and investment could be made towards the cause of road safety in Malaysia.

The use of conjoint analysis to elicit the preference of safety through people's willingness to pay in this study has successfully achieved the main objective to estimate the value of statistical life for accident injury in Malaysia. This is further supported by the consistency of the result with contingent valuation pilot study. The variation in the range of the estimates and the factors could be explained with the differences in technical implementation of both studies and the demographical diversity of the samples. It should also be realized that the values for this study are higher than previous valuation practices which may implies that people are eager on putting more value towards their safety on the road. Hence, this study suggest that the VOSL for each severe injury involving car drivers as RM 779,896 and for motorcyclist at RM 508,226. The estimates for slight injury are RM 346,813 and RM 329,492 for car and motorcycle respectively.

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APPENDIX A - CONJOINT ANALYSIS RESULT

Table 4: VOSL according to variables (RM)

(CAR)

CSV – Car Severe Injury		CSL – Car Slight Injury	
VARIABLE	**VOSL (RM)**	**VARIABL**	**E VOSL (RM)**
INCOME		**INCOME**	
500 and below	**683,381**	**500 and below**	**477,450**
501-1000	**807,605**	**501-1000**	**364,488**
1001-1500	**707,177**	**1001-1500**	**357,258**
1501-2000	**767,363**	**1501-2000**	**160,725**
2001-3000	**1,036,864**	**2001-3000**	**100,941**
3000 and above	**812,959**	**3000 and above**	**383,305**
VEHICLE OWNERSHIP		**VEHICLE OWNERSHIP**	
No	**832,973**	**No**	**423,581**
Yes	**769,861**	**Yes**	**311,186**
NO. OF YEARS DRIVING		**RACE**	
< 1 year	**756,133**	**Malay 3**	**35,358**
1 - < 5 years	**783,761**	**Chinese**	**240,524**
5 - < 10 years	**793,874**	**Indian**	**307,136**
10 - < 15 years	**1,068,429**	**Bumiputera**	**321,741**
15 - < 20 years	**1,004,928**		
20 years and more	**2,251,957**	**ACCIDENT HISTORY**	
		Family died:	
EMPLOYER		**No**	**779,644**
Government	**802,569**	**Yes**	**802,204**
Private	**786,604**		

CSV – Car Severe Injury CSL – Car Slight Injury

(MOTORCYCLE)

CSV – Car Severe Injury		MSL – Car Slight Injury	
VARIABLE	**VOSL (RM)**	**VARIABLE**	**VOSL (RM)**
INCOME		**INCOME**	
500 and below	**409,940**	**500 and below**	**313,541**
501-1000	**604,725**	**501-1000**	**388,473**
1001-1500	**662,276**	**1001-1500**	**467,704**
1501-2000	**1,186,826**	**1501-2000**	**470,754**
2001-3000	**832,956**	**2001-3000**	**445,847**
3000 and above	**854,421**	**3000 and above**	**381,095**
GENDER		**ACCIDENT HISTORY**	
		Have seen accident:	
Male	**509,706**	**No**	**328,369**
Female	**499,507**	**Yes**	**364,641**
RACE		**Have involved in accident:**	
Malay 3	**603,054**	**No**	**328,369**
Chinese	**792,747**	**Yes**	**364,641**
Indian	**652,010**	**Age**	
Bumiputera	**676,579**	**<25**	**369,713**
ACCIDENT HISTORY		**<30**	**463,479**
Have seen accident:			
No	**613,348**	**<40**	**465,681**
Yes	**495,509**	**<50**	**473,640**
		50 and above	**585,713**

EVALUATION OF LINK SPEED ESTIMATION BASED ON POINT DETECTION SYSTEM ON EXPRESSWAY

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Abstract: In the state of practice, traffic operators require real time traffic information inorder to analyze and make decision to choose the suitable traffic operation plan that could mobilize traffic safer and with less travel delay. Conventional point detection system is widely used to measure traffic parameters, namely volume, speed, and occupancy. These key traffic parameters are used to analyze traffic condition on interested segment or entire road network. Penetration of detector stations is directly correlated to the accuracy of estimated link speed because of the amount and quality of data in the calculation. This paper aimed to evaluate some simple methods for estimating link speed on expressway with low density of detector stations. Data from Expressway in Tokyo, Japan, were used. The results from the study demonstrated that the simple methods are able to represent link speed during uncongested condition but unable to represent the speed during congestion condition on expressway with low density of detector stations or long links.

Key Words: State of Practice, Traffic Information, Link Speed, Point Detection

1. INTRODUCTON

In the state of practice, traffic information is required by traffic operators to analyze and make an action on suitable traffic operation plan with an objective to efficiently manage traffic on road network. Traffic information can also be disseminated to travelers on variable message signs or on-board vehicle route guidance system so that travelers can optimize their own travel. Most of traffic information comes from traffic detection. Flow, speed, and density are known as the main key traffic parameters (data), collected by road agency, that are used to describe traffic conditions. Often, these parameters are continuously collected to monitor traffic condition on roadway in real-time basis. The inductive loop detector is widely used to measure traffic volume and occupancy. In case of using single loop detector that traffic speed is calculated using traffic volume, occupancy, and effective vehicle length (Hall and Persaud, 1988). However, calculated speed using this method is an average speed or time mean speed of vehicle traversing on small area of detector, not space mean speed which is corresponded with principle of traffic flow. This time mean speed calculated from single loop detector data was then used to estimate space mean speed. To gain closer and more detailed estimation of speed, Extended Kalman filter was introduced to the dynamics speed estimation (Dailey, 1999). However, speed estimation method using traffic volume, occupancy, and effective vehicle length is still used in practice.

Several highway agencies employed few speed calculation methods to estimate space mean speed. Traffic speed can be estimated using traffic volume and occupancy which are available from single loop detectors. Effective vehicle length is calculated by weighted average of small vehicles and long vehicles passing detection area during time interval. However, vehicle length can not be measured using single loop detector. Normally, it is predefined with constant value measured on adjacent area. For the fact that the predefined constant value of effective vehicle length is invalid, accuracy of speed estimation can be improved by dynamic effective vehicle length every time interval in order to estimate speed more accurately (Wang and Nihan, 2000). The occupancy variance obtained from single loop detector data can be used to estimate long vehicle percentage, and log linear regression model are used for mean vehicle length estimation based only on single loop outputs can be developed. The accuracy of these methods is affected by large vehicle percentage which can skew occupancy value higher than small vehicle. Estimated speed might be underestimated within this effect that can be improved using median speed in stead of mean speed because high percentage of large vehicles cannot affected estimated speed (Coifman, 2001, Coifman et al., 2003). However, speed estimation using single loop detector relied on several traffic parameters that normally measured with large errors both spatially and temporally. Traffic speed can also be directly measured using dual inductive loop detector or other detectors such as ultrasonic, microwave, infrared, and video image processing. However, those traffic surveillance systems are normally used to measure instantaneous vehicle speed traversing on any location or small space typically less than 0.8 km (Turner et al., 1998) where detection is applicable.

Moreover, it is important to obtain traffic state on each road link in real-time in order to estimate link speed and then convert it into link travel time information and detected traffic incident. Therefore, real-time spot speed data collection method and then the estimation of link speed using these spot speed data are normally carried out in practice. The easy to use and few traffic data requirement are the main concern to implement this method in practical operation.

Several factors are attributed to the accuracy of resulting information, such as spacing of detector stations and detector placement. These factors seriously impact representative spot speed which is used to reflect traffic speed measurement, and then also directly affect link speed estimation (Bertini and Lovell, 2009). Moreover, the aggregation of data collection in time interval also affects the accuracy of real-time traffic data measurement (Guo et al., 2008).

This paper aimed to evaluate simple methods that are normally used for estimating link speed on expressway. However, there are several factors affected to the estimated link speed accuracy such as detector spacing, detector placement, aggregation time interval as previously described. In order to reduce the effects, real world expressway corridor was used as case study in order to eliminate the effect of detector spacing and placement. Furthermore, traffic data provided by selected case study is aggregated to 5 minute time interval and therefore aggregation time interval effect being also neglected. This paper was organized as follows, introduction, link speed estimation methods, evaluation method, results and discussion, and conclusion and direction of future study. Finding in this paper would be performed the weakness of using simple methods for estimating link speed based on measured spot speed using upstream and downstream detector station that traffic analyzers should be realized the weakness of simple methods when it is conducted in practice.

2. LINK SPEED ESTIMATION METHODS

In order to estimate link speed from spot speed measurement, several detector stations have to be installed either on-road or off-road. Speed data can be converted from occupancy, volume, and effective vehicle length that can be measured by single loop detector. Speed data can be directly obtained using double loop or similar detectors as well. Several methods can be used to estimate link speed in practice. In this study, three simple methods that normally use in practice (Kothuri et al., 2007) for estimating link speed, namely average, weighted average, and San Antonio, were evaluated against observed link speed to apprehend the weakness of these simple methods. Three speed estimation methods are described as follows:

2.1 Average Speed

The average speed is one of the simplest methods to estimate link speed based on spot speed measurement using point detector data. Spot speed measured on upstream and downstream every time step is calculated using simple arithmetic mean as shown in equation (1). Traffic speed on link is assumed to be uniformly distributed under short time interval and short link length.

$$v_s(k)=\frac{v_u(k)+v_d(k)}{2} \tag{1}$$

where $v_s(k)$ is estimated link speed at time k, $v_u(k)$ and $v_d(k)$ is measured spot speed on upstream and downstream detector at time k respectively.

2.2 Weighted Average

The weighted average method is proposed to estimate link speed using spot speed data measured by upstream and downstream detector. This method is average link speed based on traffic flow that also simultaneously measured with spot speed under each time interval. Estimated link speed is the value nearby spot speed that is measured by the detector station with higher traffic flow as shown in equation (2).

$$v_s(k)=\frac{q_u(k)v_u(k)+q_d(k)v_d(k)}{q_u(k)+q_d(k)} \tag{2}$$

where $q_u(k)v_u$ and $q_d(k)$ is traffic flow on upstream and downstream detector station respectively.

2.3 San Antonio

This method has been used according to San Antonio Trans guide project which employs the minimum spot speed value between upstream and downstream detector station as equation

$$v_s(k)= min\big((v_{up}(k)+v_{down}(k)\,\big) \tag{3}$$

3 EVALUATION METHOD

Three simple methods which are normally used in practice for estimating link speed are evaluated in this study. Spot speed data from upstream and downstream detector data are attempted to represent link speed. In order to evaluate the three simple methods, simulation model was conducted in this study instead of real data which link speed can not be directly measured using point detector data. Simulation model was conducted in this study in order to evaluate the performance of speed estimation by the three simple methods. The evaluation is carried out for expressway traffic. However, there are several factors affected to the estimated link speed accuracy such as detector spacing, detector placement, aggregation time interval, and others. In order to decrease the effects, real world expressway corridor was used as a case study to eliminate the effects of detector spacing and placement. The site study and evaluation method are described as follows.

3.1 Site Study

A 11.22 km. road section of the Matsubara line of the Hanshin expressway in Osaka, Japan between Nanba and Matsubara junction in the outbound direction was selected as the site study. Figure 1 and 2 show the study area of Hanshin expressway and schematic diagram of Osaka to Matsubara selected section. The subject study section has two lanes in one traffic direction for the whole length of the section. The section consists of two on-ramps, five offramps, and eight overhead ultrasonic detectors installed.

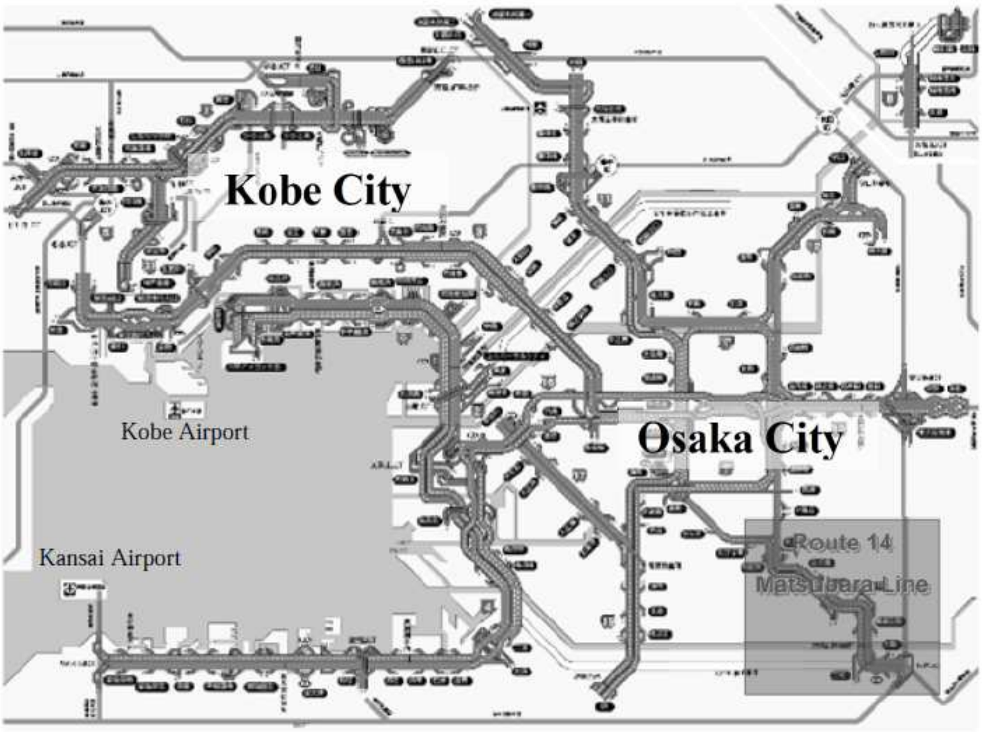

Figure 1. Matsubara line on Hanshin expressway

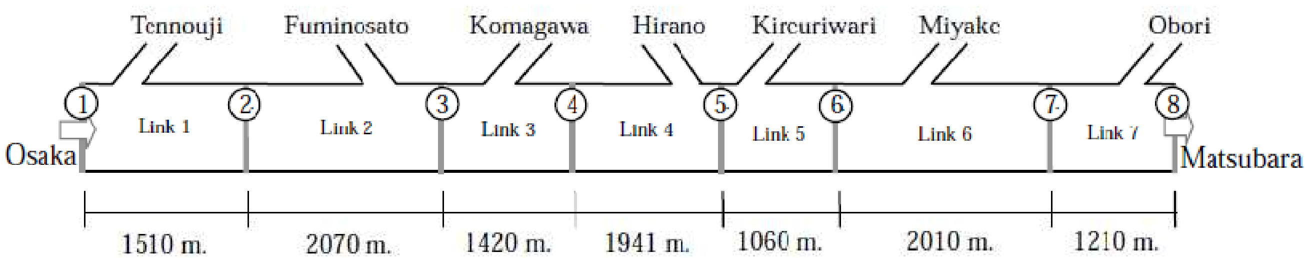

Figure 2. Schematic diagram of Matsubara Line

Traffic data were collected by eight main line detectors, two on-ramp detectors, and five offramp detectors. The data were collected for 24 hours using overhead ultrasonic detectors on November 1, 1994. Traffic data was aggregated every 5 minutes including traffic volume, traffic speed, and occupancy then aggregation time interval effect is also neglected. Traffic simulation model of selected site study was developed using PARAMICS v.5.2 development suite and then the model was calibrated based on the idea of combinatorial (ROTWANNASIN et al., 2009). Traffic data on 8 detector stations were used as upstream and downstream traffic data of 7 links. Individual link speed was also extracted from simulation model, which were executed from 7:00 until 23:00 in order to generate observed link speed and to be used in comparing the accuracy of link speed estimation with those from three simple methods.

3.2 Evaluation Method

In order to evaluate the three simple link speed estimation methods, estimated and observed link speed are plotted as diagonal plot link by link in order to investigate the under or over estimation of each simple method. Consequently, mean absolute percentage error (MAPE) is conducted in this study to measure how large of estimation error by comparing observed link speed with estimated link speed as shown in equation (4).

$$\mathrm{MAPE} = \frac{1}{n} \sum_{k=1}^{n} \left| \frac{v_{obs}(k)-v_{est}(k)}{v_{obs}(k)} \right| \quad (4)$$

Where $V_{obs}(k)$ is observed link speed at time k and $V_{est}(k)$ is estimated link speed at time k. MAPE is separately calculated by two traffic conditions which are uncongested and congested condition.

4 RESULTS AND DISCUSSION

Seven links were defined by ultrasonic detector of 8 stations equipped on Matsubara line of Hanshin expressway. Three selected simple methods were calculated link speed using upstream and downstream detector as described in equation (1) - (3). Estimated and observed link speed of each link was plotted as shown in Figure 3 to realize the over- and underestimation using these simple methods.

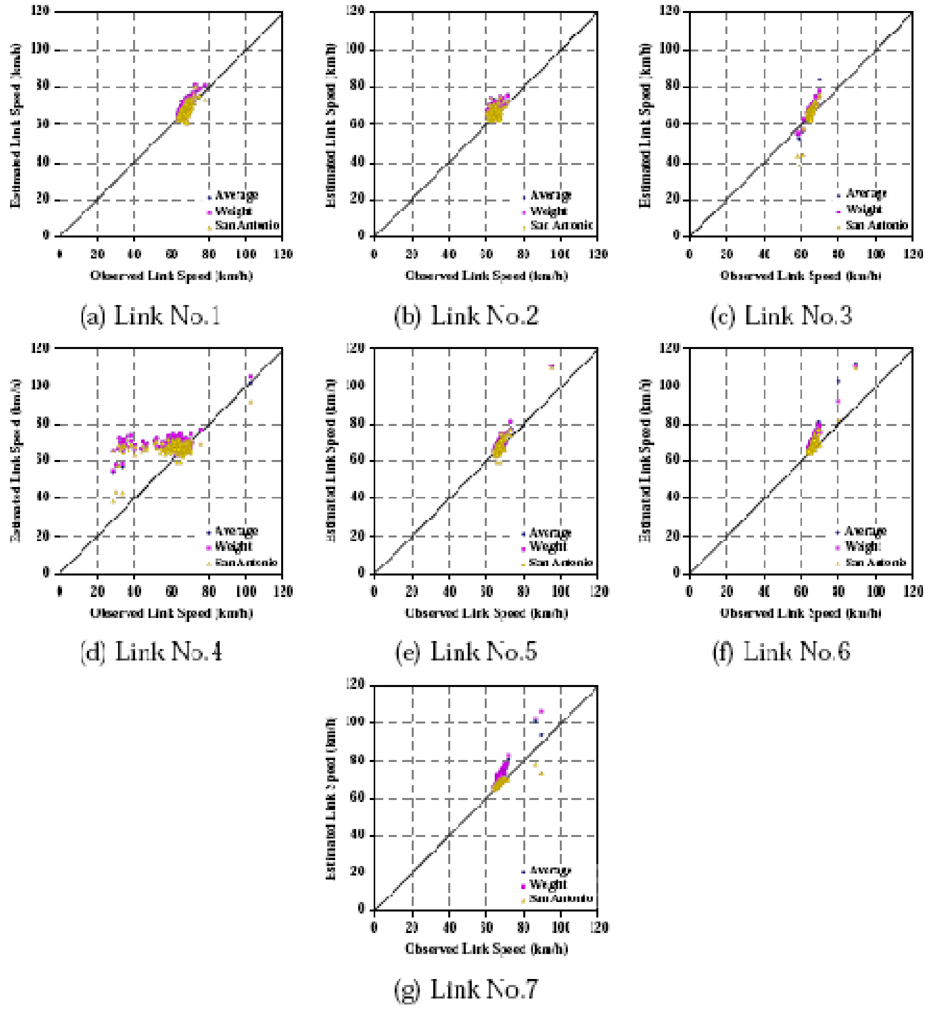

Figure 3. Diagonal Plot Between Estimated and Observed Link Speed

Figure 3 shows that the 1st, 2nd, and 3rd link have speed ranged between 60 and 80 km/h in which three simple methods performed quite well to represent the link speed using speed data from upstream and downstream detectors. However, it has large error on the 4th link, almost of estimated link speed are higher than observed link speed. For the 5th, 6th, and 7th link have speed ranged between 60 and 80 km/h, similar to the first three links. Estimated link speed values higher 80 km/h observed on the 4th, 5th, 6th, and 7th link occur during 7:00 and 7:10 when the initial period of simulation was running, the speed can be ignored.

The absolute percentage error (APE) was calculated every 5 minutes and then minimum, maximum, average, and standard deviation of APE are summarized in Table 1. If MAPE of 20% is the maximum MAPE that could be accepted, three simple methods have shown the MAPE below 20% except the 4th link that MAPE is higher than 20% while all MAPE is below 20% using San Antonio method. However, three simple methods show the highest APE and standard deviation is also quite high on the 4th link. The 4th link was investigated in more details to understand why this link shows the high value of APE.

Table 1. MAPE and APE as Minimum, Maximum, and Standard Deviation(%)

Method		Link No. 1	2	3	4	5	6	7
Average	MAPE	4.38	5.14	4.16	20.28	3.78	7.16	5.03
	Min.	0.00	0.03	0.05	0.04	0.06	1.69	0.27
	Max.	11.30	19.00	20.52	127.27	16.61	28.53	16.77
	S.D.	2.38	3.39	2.30	29.08	2.50	3.49	2.44
Weighted average	MAPE	4.56	5.10	3.97	20.37	3.80	6.72	5.42
	Min.	0.09	0.06	0.05	0.01	0.03	1.48	0.08
	Max.	11.39	19.00	12.07	127.70	16.88	25.09	19.51
	S.D.	2.43	3.33	2.00	29.19	2.55	2.99	2.91
San Antonio	MAPE	2.50	3.91	3.10	17.40	2.72	4.01	1.70
	Min.	0.04	0.08	0.00	0.02	0.00	0.08	0.00
	Max.	11.27	18.80	34.55	124.54	15.32	23.76	17.76
	S.D.	2.23	3.00	3.83	25.99	2.15	2.92	1.70

As mentioned above, a large error can be seen on the 4th link where three simple methods showed an over-estimation in representing link speed. Furthermore, the maximum value of APE is quite high although the MAPE is close to 20% when using average and weighted average method or below 20% when using San Antonio method. In order to investigate in details, time dependent of link speed and APE on the 4th link are plotted as shown in Figure 4 and 5.

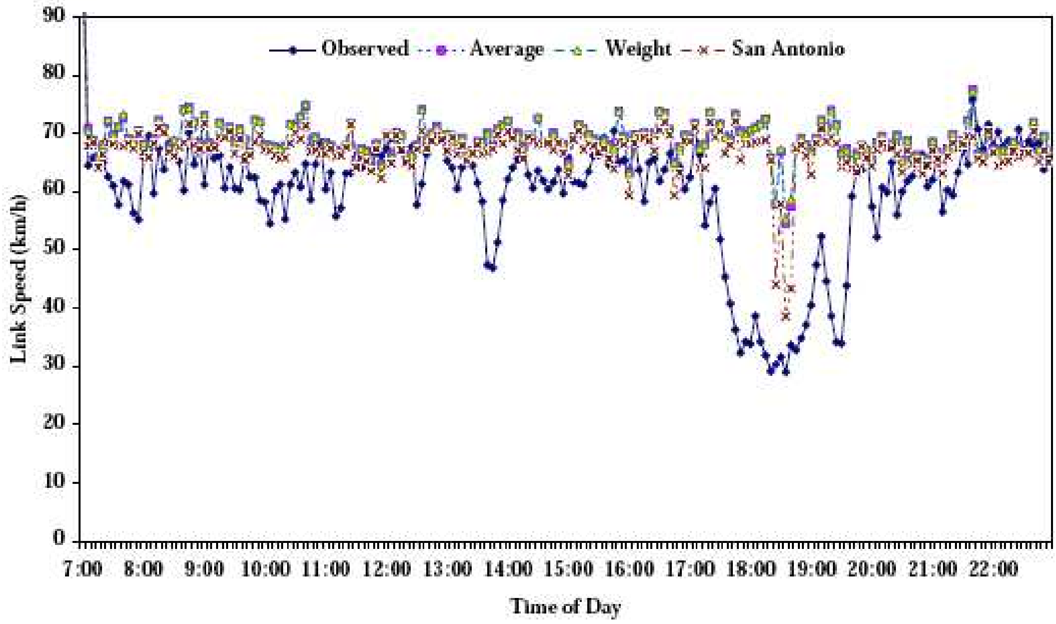

Figure 4. Time Dependent of Link Speed on the 4th Link

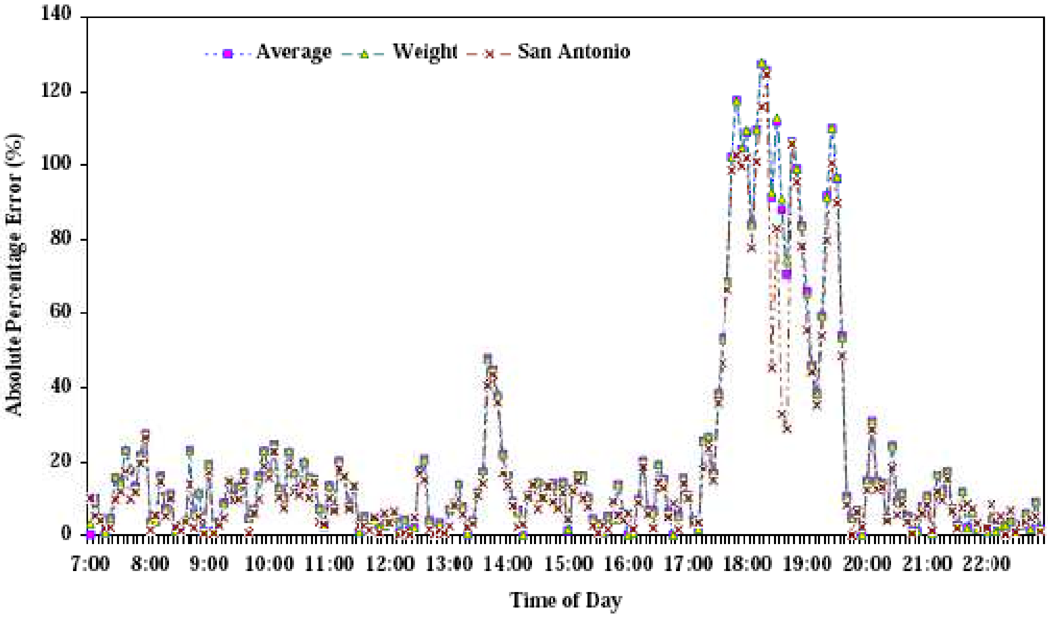

Figure 5. Time Dependent of Absolute Percentage Error on the 4th Link.

Figure 4 shows that the link speed on the 4th link drops during 17:15 until 19:55 when three methods are badly performed during this period with high value of APE as illustrated in Figure 5. Therefore, the values of MAPE during uncongested and congested condition were separately calculated and was shown in Table 2. The authors define period with speed drop as congested condition and otherwise as uncongested condition. It was found that three simple methods are quite well performed during uncongested condition but badly performed during congested condition.

Table 2. Mean Absolute Percentage Error (%)

Method	Uncongested	Congested
Average	9.77	70.94
Weighted average	9.93	70.88
San Antonio	8.32	61.72

In this study, even if the effects of detector spacing and placement are neglected, we can not deny that these two effects seriously impact the reliability of link speed represented by the estimation of upstream and downstream speed of the link. Length of the 4th link is 1941 m, which is considered a long link that data from upstream and downstream detectors may not well represent link speed. Traffic speed measured at detector number 4 (upstream) and 5 (downstream) were plotted and compared with the observed link speed as shown in Figure 6.

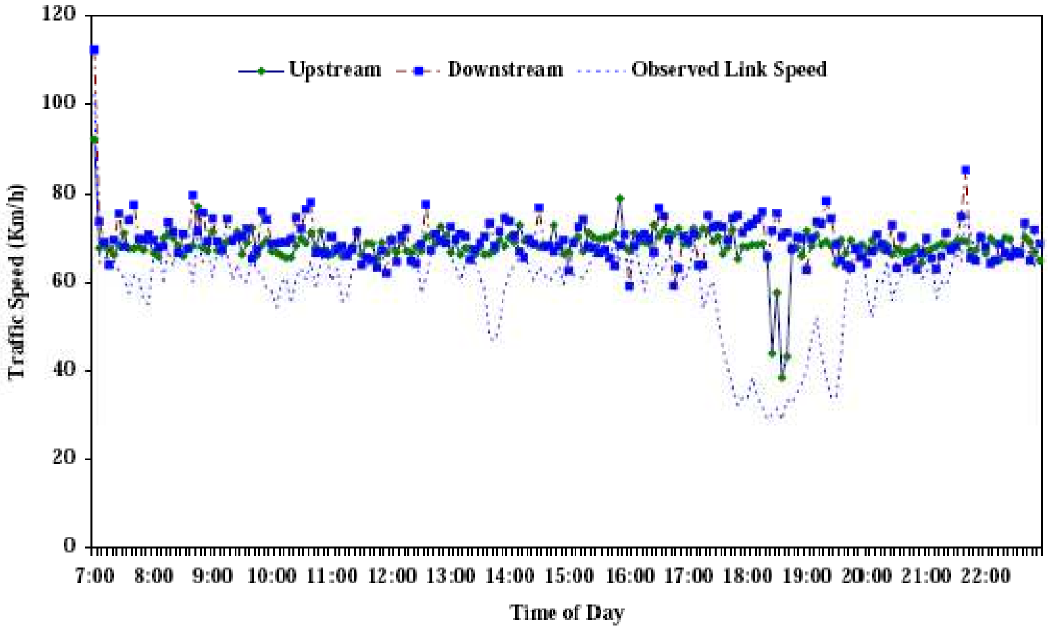

Figure 6. Traffic Speed on Upstream and Downstream Detector Station Against Link Speed on the 4th Link

Figure 6 shows that observed link speed initially drops at 17:15 while detector station can capture speed drop at 18:20. It is too much lag that either upstream or downstream detector can capture this speed drop. The link length is too long to use spot speed from upstream and downstream detector station for representing link speed especially during congested condition. Traffic analyzer should realize this fact when they have to estimate link speed on expressway corridor with low density of detector stations similar to this case study. However, the effect of detector station numbers (reducing spacing) on the reliability of link speed estimation using simple methods can not be reported within this study.

5. CONCLUSION AND DIRECTION OF FUTURE STUDY

Traffic speed on expressway especially link speed is an important traffic parameter that traffic operators are required. Traffic detectors such as loop detector, ultrasonic, infrared, and video image processing are conducted on expressway operation system in many countries. There are several limitations of these equipment such as detector station spacing, detector placement, and aggregation time interval. Traffic analyzers should realize these limitations when analyze traffic parameters using traffic data measured by these traffic detection system. Especially, simple methods that are normally used to estimate link speed using upstream and downstream speeds measured on both side of the links.

The findings in this paper illustrate that the weakness of using the three simple methods to estimate link speed on expressway are mainly large error under congested condition but it is quite well performed under uncongested condition. Most of estimated link speeds during congestion period are overestimated. The effect of detector spacing and placement might be the serious factors that impact with the reliability of estimated link speed using simple methods. According to the case study, the length of the 4th link is too long to conduct the spot speed measured from upstream and downstream detector stations for representing link speed.

For the future study, the improvement of speed estimation method could improve the reliability of estimated link speed based on upstream and downstream detector data which normally and presently equipped on expressways. Improved methods should be uncomplicated to implement.

However, detector density improvement is the suitable solution but it is a huge cost to invest on infrastructure. The benefit of using these kinds of traffic data and investment cost that expressway operators have to be traded-off. Another solution to improve the reliability of estimated link speed is the application of intelligent transportation system such as automatic vehicle location (AVL) and automatic vehicle identification (AVI) which are vehicles equipped GPS unit and toll tag readers in case of expressway. There are several techniques to integrate these ITS data with the existing detector to improve the reliability of estimated link speed.

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COMPARISON OF SINGLE AND TANDEM SPEED HUMPS IN SPEED REDUCTION

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Abstract: Although there are no legislations governing the installation of speed humps in Taiwan, their existence is of need in certain road sections, in particular, traffic calm areas. This study compares the effectiveness of single and tandem speed humps in speed reduction. Data collected include the distance from the speed humps where drivers brake to reduce speed, which would shed light on the effective area of speed humps. Difference in speed reduced by single and tandem speed humps are also determined by the before-after study to compare the effectiveness of these two types of speed humps in speed reduction. The results reveal that speed humps are effective in reducing speed and that tandem speed humps are more effective than single speed humps in speed reduction. The findings in this study can be useful references for traffic engineering and can serve as guidelines for deciding which type of humps to be installed on certain road sections.

Key Words: **S**ingle speed hump, Tandem speed hump, Speed reduction

3. INTRODUCTON

Driving at a certain speed involve risks on the drivers and pose danger to the passengers and pedestrians. Hence, measures are taken to control and reduce speed especially at road sections where the right-of-way for different road-users are in conflict. Speed control or reduction not only can maintain steady traffic flow in accordance with the design road capacity, but can also ensure safety for drivers, passengers and pedestrians. Among the various means of speed control/reduction, speed hump is one of them. Although speed humps are very effective in keeping vehicle speed down, their use is sometimes controversial as they can cause noise and possibly rider discomfort and vehicle damage if taken at too great a speed. As a traffic-calming tool designed to limit driving speed, circular profile speed hump is a raised area or ridge with heights ranging from 5 cm to 12 cm and lengths varying from 3 meters to 4 meters, and another flat top speed hump is of similar heights to the circular profile speed hump, but has straight approach and departure ramps (typically 1:10 to 1:15), the lengths varying from 2 meters to 7 meters *(1)*.

With respect to road safety engineering, Ogden considered road humps, which cause vertical displacement of a vehicle, highly effective in causing vehicles to reduce speed in their vicinity. In fact, such devices, which achieve traffic calming, not only improve road safety, but also address the wider issue of the ‘quality of life’ in our town and villages. Compared with other speed reduction devices such as rumble strips, speed humps seem to be more effective.

In the Manual on Uniform Traffic Control Devices (MUTCD) issued by the Federal Highway Administration (FHWA), USA in 2000 *(2)*, there are general specifications laid down while such can be adapted to suit the laws and needs of different states. Though with some differences, the installation of speed humps in various states in USA in general first requires experts’ opinion. Then only with the consent of the residents in the vicinity of the speed hump to be installed can work proceed. The installation should also comply with the specifications laid down by the Institute of Transportation Engineers (ITE) *(3)* and American Association of State Highways and Transportation Officials (AASHTO). Upon completion, the effectiveness of the speed hump installed should be monitored for over six months before it becomes a permanent installation.

In contrast, there are no legislations governing the design and installation of speed humps in Taiwan. In the “Guidelines for Installation of Traffic Signs, Markings, and Signals” published in 1995 *(4)*, there are some clear specifications provided for the installation of rumble strips but nothing has been said on speed humps. As mentioned in the Guidelines, rumble strips serve to warn drivers of the special road conditions ahead and alert them of the need to reduce speed. Moreover, related research on speed humps and their effectiveness in Taiwan has been scarce. Woo and Chen *(5)* have found support for the effectiveness of speed humps in reducing speed. Similarly, Chen and Lin *(6)* also found that the vertical displacement of the vehicle due to speed humps caused discomfort to drivers. As a result, on seeing road humps ahead, drivers tend to reduce speed.

To make up for the deficiency in research on speed humps, this study examines and compares the effectiveness of single and tandem speed humps in speed reduction. There are two types of speed humps commonly used in Taiwan: single speed hump and tandem speed hump. Owing to their different configuration, these two types of speed humps elicit different responses from the drivers. Assuming that tandem speed humps cause greater discomfort to drivers and passengers, we hypothesize that they will be more effective than single speed humps in reducing speed. Through onsite observations, this research determines the effective area of speed humps; and through a before-after study, the effectiveness of single and tandem speed humps in speed reduction are compared.

2. RESEARCH METHOD

2.1 Experimental Design

The difference in speed attributed to speed humps is indicative of their effect in speed reduction. On seeing the speed humps ahead, drivers will have different response. While some may start reducing the speed at a far distance from the speed hump, some may only press the brake when in close proximity to the speed hump. Factors affecting the time when

drivers will reduce speed include the condition of the vehicle itself as well as the skill and experience of the driver. The experiment involves two stages as follows.
Stage I aims to determine the effective distance of speed humps. Horizontal lines are marked in parallel at equal distances from the single and tandem speed humps. On seeing the speed humps ahead, approaching vehicles will reduce speed as indicated by the rear braking lights being on. The line crossed by the vehicle when rear braking lights are first on is recorded. Statistical analysis of the data collected in this stage can help determine the effective distance of speed humps.

Stage II aims to examine the effectiveness of speed humps in speed reduction and the time points when drivers begin reducing speed. From the results obtained in Stage I, the road section between the 5_{th} and 95_{th} percentiles will become the confidence interval. The two ends of this confidence interval are the two checkpoints where the speed of the passing vehicles is measured in the before-after study. The far end denotes the minimum up-stream distance from speed humps, beyond which none of the approaching vehicles reduce speed; while the near end denotes the maximum up-stream distance from speed humps, within which all of the approaching vehicles reduce speed.

Speed reduction attributed to the presence of speed humps can be obtained by calculating the difference in speed between these two ends. Hence, comparing such difference for single and tandem speed humps can shed light on their relative effectiveness.

2.2 Site Selection

Speed humps once installed serve to reduce speed of passing vehicles. Such constraints will affect the flow of traffic and road capacity. According to Ponnaluri, speed humps can only be installed on two-lane road sections in a residential neighbourhood with a daily flow of less than 3000 vehicles and mean speed of below 30 mph *(7)*. Hence, speed humps are generally found in road sections of a community or on campus with low vehicle flow but the need to reduce speed.
In this study, the road section chosen is located at the entrance of Tsing Hua University (THU), Taiwan. Figure 1 displays the layout of the site selected. As can be seen, both single and tandem speed humps are installed. They are at a distance of 70.1 meters apart, which can facilitate the comparison of the effectiveness of the speed humps in speed reduction. At one end of the experimental road section is another single speed hump at a distance of 39.3 meters from the single speed hump under observation; while at the other end of the road is a check station, 30 meters apart from the tandem speed humps under observation. This can ensure that vehicles approaching the speed humps under observation have similar initial speeds close to 0, which can help minimize deviation. Moreover, the mean hourly traffic flow at this site is around 100 vehicles (both inbound and outbound). During peak hours, the traffic flow is slightly higher, but the total daily traffic flow is less than 3000 vehicles. The users of this road section are mainly students and staff of THU, making the types of vehicles passing through this road section fairly uniform.

2.3 Experimental Setup

To assess the effective distance of the speed humps, white lines of 1 m long and red lines of 50 cm long drawn using chalk are placed alternately at 50 cm distance parallel from the speed hump. To avoid being confused as rumble strips, these lines do not stretch across the entire width of the lane. The marks stretches over 15 m from the speed hump as pilot onsite observation showed that most vehicles approaching the speed humps will reduce speed around 0-10 m from the hump with few drivers braking beyond 15 m from the hump. A laser gun is employed to measure the speed of the vehicles at the different checkpoints during later stages *(8)*.

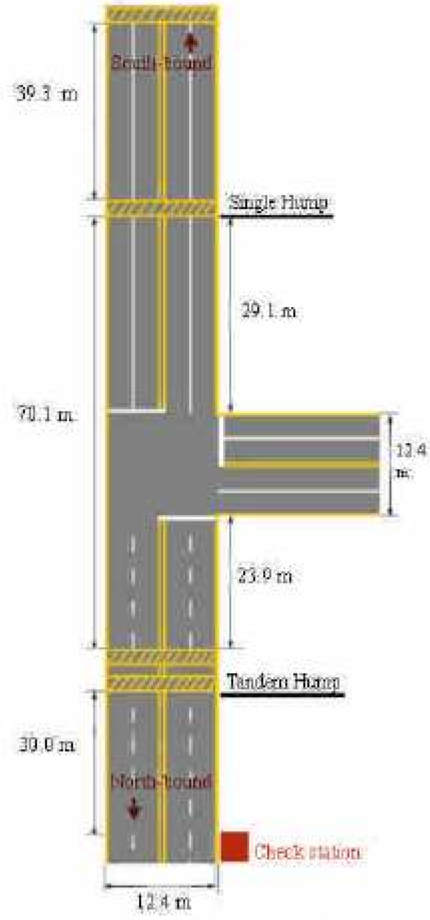

Figure 1 Layout of observation site.

2.4 Data Collection & Analysis

Video recording are made on four different road sections: (1) northbound with single speed hump, (2) southbound with single speed hump, (3) northbound with tandem speed humps, and (4) southbound with tandem speed humps. A 2-hour recording is made for each road section, from which 200 samples are extracted, making up a total of 800 samples for analysis. The rear braking lights being on is taken as indicative of the speed reduction response of the driver in face of the speed hump(s) ahead. The chalk line crossed when the rear braking lights are on denotes the distance from the speed hump when the approaching vehicle reduces speed.

However, the following samples extracted from the recorded images are excluded from data analysis to eliminate unnecessary bias.

1. Vehicles that are preceded by another vehicle, pedestrian or bicycle on the traffic lane.
2. Trucks or buses
3. Vehicles exiting from a roadside parking space.
4. Vehicles cutting into the observed road sections from the T-junction on the side.
5. Vehicles braking at a distance more than 15 m from the speed hump(s).

In each of four different road sections mentioned above, speed of vehicles are measured at the aforementioned far end and near end. The difference in speed for single speed hump (ΔS) and tandem speed humps (ΔT) are calculated by subtracting the speed measured at near end from that at far end. The four data groups obtained for the northbound and southbound traffic at the single and tandem speed humps are as follows:

Single Hump Northbound: $\Delta Sn = Snf - Snn$
Tandem Hump Northbound: $\Delta Tn = Tnf - Tnn$
Single Hump Southbound: $\Delta Ss = Ssf - Ssn$
Tandem Hump Southbound: $\Delta Ts = Tsf - Tsn$

Only vehicles passing through both types of speed humps consecutively are included in the before-after study. The criteria for exclusion of samples from analysis are the same as previous stage. Two hundred samples each from northbound and southbound vehicles are collected, making a total of 400 samples. Comparison is also made between the northbound and southbound vehicles using paired-samples T-test.

3 RESULTS AND DISCUSSIONS

Table 1 displays the results of the experiment. Northbound vehicles with tandem speed humps ahead begin braking at an average distance of 9.73 meters, which is the highest among the four road sections observed, followed by northbound with single speed hump and southbound single speed hump, with the least average distance observed for southbound vehicles with tandem speed humps ahead. This indicates that drivers on seeing speed humps ahead will tend to reduce speed.

Both southbound vehicles heading toward the single speed hump and northbound vehicles heading toward the tandem speed humps show larger standard deviations of 3.97 and 5.02, respectively. This may be accounted for by the longer road section for deceleration, which may affect the braking distance.

Table 1 Points of Braking

	Single speed hump		Tendem speed humps	
	Northbound	Southbound	Northbound	Southbound
Mean distance (m)	8.34	6.55	9.73	5.40
Median	9.00	5.00	10.00	5.00
Mode	11.00	0.00	14.00	2.00
Standard deviation	3.83	3.97	5.02	3.24
5^{th} percentile	1.00	0.00	1.00	1.00
95^{th} percentile	14.00	13.00	17.00	11.05

On the four road sections, more northbound vehicles tend to brake at more than 15 meters from the tandem speed humps. Hence, the chalk markings were extended to 20 meters from the speed hump in the later part of the experiment.

Table 2 lists the mean speed of northbound and southbound vehicles before speed reduction on seeing the speed humps ahead. The mean speed of northbound vehicles is greater than that of southbound ones. It can be attributed to the relief of the road, which is gently sloping downward to the north. This may have caused the difference in mean speed between northbound and southbound vehicles.

Table 2 Mean Speed before Speed Reduction

Direction	Single speed hump	Tendem speed humps	Mean speed	Standard deviation
Northbound	23.00	23.06	23.03	3.73
Southbound	21.90	21.52	21.71	4.12

Figure 2 shows the distribution of data points. As can be seen, the data points are mostly concentrated to the right of the 45^{o}degree line, which indicates obviously that there is significant reduction in speed for both northbound and southbound vehicles on seeing the speed humps ahead.

Tables 3 and 4 displays the paired-samples T-test results for northbound and southbound vehicles, respectively. Speed reduction for northbound traffic approaching tandem speed humps (ΔTn) is 2.17 kph higher than that approaching single speed humps (ΔSn). The t-value is 1.96 indicating significant difference in speed reduction between single speed hump and tandem speed humps for northbound vehicles. Similarly, as seen in Table 4, speed reduction for southbound traffic approaching tandem speed humps (ΔTs) is 1.72 kph higher than that approaching single speed humps (ΔSs). There is also significant difference in speed reduction between single speed hump and tandem speed humps for southbound vehicles. Moreover, comparing Tables 3 and 4 also reveals that there is greater reduction in speed for northbound vehicles than southbound vehicles regardless of the type of speed humps.

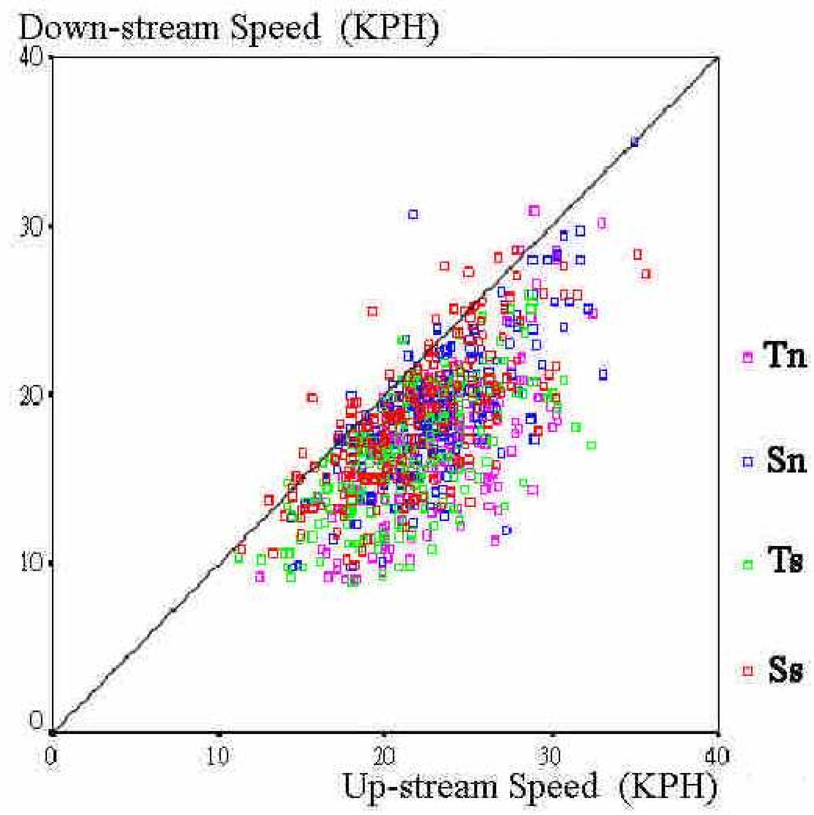

Figure 2 Distribution of data points.

Table 3 Difference in Speed Reduction for Northbound Vehicles

Paired samples statistics								
	Mean		N		Std.Dev.	Std.Err.Mean		
ΔTn (Tandem)	6.00		200		3.09	0.22		
ΔSn (Single)	3.82		200		2.94	0.21		
Paired samples correlations								
	N				Correction	Significance (Sig.)		
Difference between ΔTn& ΔSn	200				0.448	0		
Paired samples test								
Difference between ΔTn& ΔSn	Paired differences					t	df	Sig.
	Mean	Std.Dev.	Std.Err. Mean	95% C.I.				
				Lower	Upper			
	2.17	3.17	0.22	1.73	2.62	9.7	199	0

Table 4 Difference in Speed Reduction for Southbound Vehicles

Paired samples statistics								
	Mean		N		Std.Dev.	Std.Err.Mean		
ΔTn (Tandem)	5.05		200		3.22	0.23		
ΔSn (Single)	3.33		200		3.10	0.22		
Paired samples correlations								
	N				Correction	Significance (Sig.)		
Difference between ΔTn& ΔSn	200				0.438	0		
Paired samples test								
Difference between ΔTn& ΔSn	Paired differences					t	df	Sig.
	Mean	Std.Dev.	Std.Err. Mean	95% C.I.				
				Lower	Upper			
	1.72	3.35	0.24	1.25	2.18	7.24	199	0

4 CONCLUSIONS

Past works have evidenced the effect of speed humps on drivers'behaviour, in particular, in reducing speed. Our results are consistent with previous findings. Nearly all vehicles brake to reduce speed on seeing the speed humps ahead in order to minimize the discomfort caused by the vertical displacement of the vehicle when passing through the humps. Moreover, comparing the reduction in speed attributed to the speed humps reveals that tandem speed humps can result in a greater speed reduction than single speed humps.

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APPROACH OF A METHODOLOGY FOR ROAD DESIGN GUIDELINE IMPLEMENTATION IN THAILAND BASED ON INTERNATIONAL TECHNOLOGY AND KNOWLEDGE TRANSFER

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Abstract: In the past decades several successful road traffic safety measures were implemented to improve road safety situation in various countries around the world based on international technology and knowledge transfer. A new methodology for implementing design guidelines based on international technology and knowledge transfer is described in this paper. The objective of the proposed methodology is to foster the development and implementation of design guidelines for road infrastructure in emerging and developing countries. The transfer and adaptation of proven European design methods and technologies is an appropriate measure to close existing knowledge gap and help improve road traffic safety in these countries.

The paper was prepared by the partners of the international network "NICE on RoadS – EU-Asia Network In Competence Enhancement on Road Safety" with financial support from the European Commission.

Key Words: road traffic safety, technology transfer, knowledge transfer, NICE on RoadS

1. INTRODUCTON

Road traffic accidents are a trans-boundary problem affecting European as well as Asian countries. The socio-economic cost of road accidents with immense human suffering is far too high a price to pay for mobility. Around the world, national and international organisations have set the reduction of the number and the severity of road accidents as one of their major transport policies.

For instance in 2001 the European Commission declared in the **White Paper** "*European transport policy for 2010: time to decide*" the ambitious objective to reduce the number of fatalities on roads by half by 2010. Also several Asian countries proclaimed similar objectives in their countries. For instance in Thailand the **Thailand Road Safety Manifesto (TROSAMAN)** proclaimed the goal to substantially reduce the number of road deaths by setting the objective of saving 5.000 lives in 5 years.

"For the past five years, 2002-2006, some 66,300 people died in road traffic accidents in Thailand or an average of 13,260 deaths per annum. Some 5,0 million people were injured, some of them severely. The economic loss resulted from traffic accidents were estimated at 232,000 million Baht, corresponding to approximately 2,81% of the country´s Gross National Product" (Thailand Road Safety Manifesto, 2007).

In 2009, the Thai government has adopted a similar target to those proclaimed by the UN Road Safety Collaboration which called for 50% reduction in number of fatalities worldwide by 2020.

The **World Health Organisation** (WHO, 2004) pointed out the need for activities to counteract the current situation, otherwise "without increased efforts and new initiatives, the total number of road traffic deaths worldwide and injuries is forecast to rise by some 65% between 2000 and 2020, and in low-income and middle-income countries deaths are expected by as much as 80%"

In response to this problem the WHO (2004) has recommended that "in developing countries, …, the priority should be the import and adaptation of proven and promising methods from developed nations, and a pooling of information as to their effectiveness among other lowincome countries".

Following this recommendation, a new approach for design guideline implementation based on international technology and knowledge transfer" will be described in this paper. This approach, which is as far as the authors know, is the first of its kind being carried out in Thailand in the area of road design, gives an overview of working steps and important aspects which should be considered for an efficient technology and knowledge transfer in order to effectively improve road traffic safety.

This paper was prepared by the partners of the international network "NICE on RoadS" in the framework of the Thai-EC project "Improving Road Traffic Safety in Thailand – A Common Challenge for European and Thai Universities" with financial support from the European Commission (www.nice-roads.com).

2. INFLUENCING ELEMENTS - AREAS OF ROAD TRAFFIC SAFETY ACTIONS

A study originally published by Treat (1977) revealed that the influencing elements HUMAN, VEHICLE and ENVIRONMENT are to be blamed for the occurrence of accidents. Following this approach a traffic accident is a result of the failure of at least one of these elements as shown in *Figure 1a*.

A lot of influencing variables can be assigned to the influencing elements, for instance: Element 1: **"HUMAN"** includes the behaviour of the drivers and other road users; Element 2: **"VEHICLE"** includes e.g. the intrinsic safety of the vehicles with the view on technical aspects; Element 3: **"ENVIRONMENT"** includes amongst others the intrinsic safety of roads and environment with the view on the design of road infrastructure.

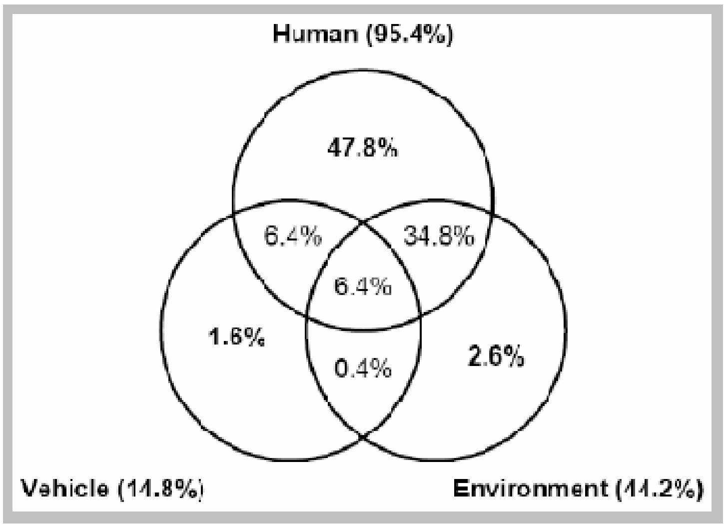

Figure 1a. **Influencing elements on road traffic safety (Treat, 1977)**

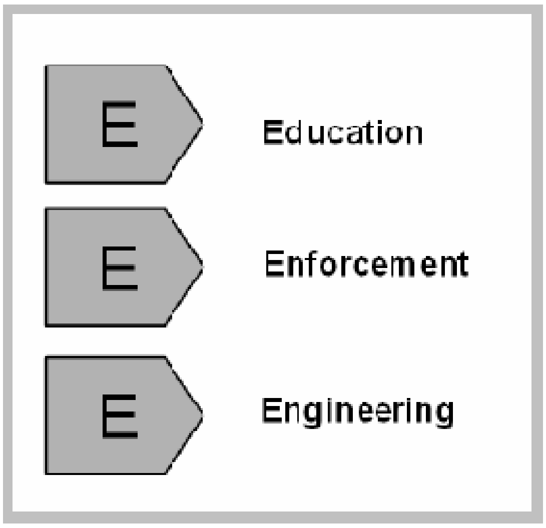

Figure 1b. **Triple-E Model**

Furthermore one can distinguish between three action areas which comprise measures to address road traffic safety problems - also known as "Triple-E Model" (see *Figure 1b*).

The first **"E"** (**Education**) comprises different education related measures to improve road safety like e.g. training courses for drivers or children. The second **"E"** (**Enforcement**) comprises measures which punish road users if they do not follow official rules and regulations in road traffic like for instance drunken driving or exceeding speed limits. The third **"E"** (**Engineering**) deals with measures relating to engineering aspects, here for instance with the design of road infrastructure which have, beside other sub-areas of engineering (e.g. design of vehicles, etc.) a significant influence on road traffic safety.

3. EFFICIENT ROAD SAFETY MEASURES

In the last decades different road safety measures were implemented in European countries to improve road safety. These road safety measures addressed all influencing elements and action areas as mentioned above.

The trend in fatalities in road traffic accidents in Germany is shown in *Figure 2* as an example during the period 1953 to 2008. Some selected road safety measures and the respective points of introduction are marked in this figure. Measures like the introduction of speed limits, maximum blood alcohol limits, obligatory use of helmets and seat belts contributed to improved road traffic safety. Of course, beside the measures mentioned, other aspects like e.g. the technical development of vehicles and developments in the design of road infrastructure also had a strong influence on road traffic safety. Nevertheless it is estimated that the above mentioned measures had a significant influence on the decrease of the number of fatalities in road traffic accidents in Germany.

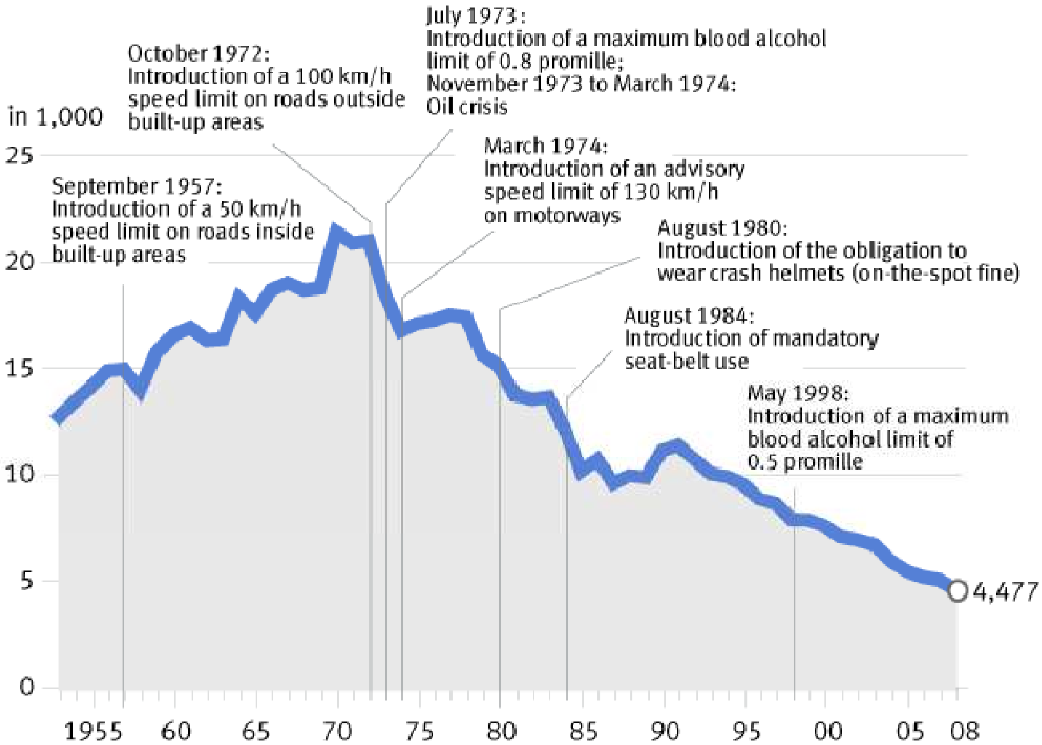

***Figure 2*. Trend in the number of fatalities in road traffic accidents in Germany**
Source: Statistisches Bundesamt (2009)

Various road traffic safety measures and methods were successfully implemented related to the influencing-element **"ENVIRONMENT"** and the action-area **"Engineering"** in Germany in the last decades. In a series of cases the new measures and methods were the result of international technology and knowledge transfer, like e.g. the implementation of Road Safety Audits in the planning process of roads. Here German experts took comprehensive experiences from other countries around the world, e.g. European countries Australia, into consideration in the preparation process of their national guidelines.

Another impressive example is the introduction of the compact one-lane roundabout as a new intersection type in Germany about two decades ago. Good experiences gained from this intersection type in several countries, e.g. France and the United Kingdom were the main reason why this intersection type was introduced in Germany. Nowadays an estimated 3000 to 5000 compact one-lane roundabouts are in operation in Germany (Brilon, 2008). Several comparisons and before-after studies came to the conclusion that compact one-lane roundabouts can serve traffic volumes with a high safety level. For this reason the application of this intersection type is acknowledged as an appropriate measure for redesign of existing intersections (see *Figure 3*) and for the design of new intersections in the road network.

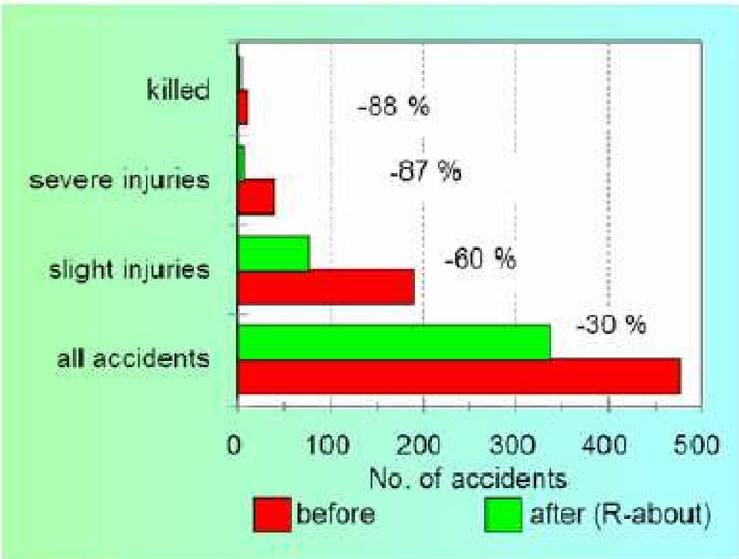

Figure 3. **Before-after study of intersections which were rebuilt to compact one-lane roundabouts in Germany, Source: Brilon (2008)**

Similar experiences were also obtained with roundabouts in various countries around the world as shown in Table 1 (FHWA, 2000).

Table 1. **Mean crash reductions by re-design of intersections into roundabouts Source: FHWA (2000)**

Country	**Mean Reduction (%)**	
	All Crashes	**Injury Crashes**
Australia	41-61%	45-87%
France	-	57-78%
Germany	36%	-
Netherlands	47%	-
United Kingdom	-	25-39%
United States	37%	51%

Figures shown in Table 1 give a clear example to the fact that the implementation of similar design approaches in the design of road infrastructure around the world was an effective measure to improve road traffic safety. Efficient transfer of technologies and related knowledge between organisations and institutions at international and national level can foster the process of implementation and diffusion of successful design methods of road infrastructure.

Several other design methods and measures and their impact on road traffic safety are explained by provision of comprehensive comparison studies by Elvik et al. (2009).

4. TECHNOLOGY AND KNOWLEDGE TRANSFER

4.1 Context

The WHO (2004) recommended technology and knowledge transfer as an appropriate way to improve road traffic safety: "in developing countries, …, the priority should be the import and adaptation of proven and promising methods from developed nations, and a pooling of information as to their effectiveness among other low-income countries". This statement can also be applied to emerging countries like Thailand.

Following this recommendation different road safety manuals were published in the last years e.g. by World Health Organisation (WHO), Global Road Safety Partnership (GRSP), PIARC World Road Association and FIA Foundation (FIA) in order to foster the implementation of successful road safety measures (cf. *Figure 2*) like:

- wearing helmets (WHO, 2006),
- counteracting drinking and driving (GRSP, 2007),
- introducing road safety audits (PIARC, 2007),
- introducing speed management (GRSP, 2008),
- and considering seat-belt use and child restraints (FIA, 2009).

Furthermore several guidelines for the design of road infrastructure were implemented in various European countries with essential input based on international technology and knowledge transfer in the last decades.

Following the recommendation of WHO and good experiences made in Europe, the network partners of "NICE on RoadS - EU-Asia Network in Competence Enhancement on Road Safety" are of the opinion that development and implementation of new design guidelines, based on international technology and knowledge transfer can contribute significantly to safer roads in Asian countries like Thailand in the future.

The impact of improved road infrastructure (influencing element: ENVIRONMENT) on road traffic safety can be estimated on basis of *Figure 1a*.

In the framework of the Thai-E.C. project "Improving Road Traffic Safety in Thailand – A Common Challenge for European and Thai universities" five partner universities from Germany, Hungary and Thailand are developing and testing a "Methodology for design guideline implementation based on international technology and knowledge transfer".

With the planned methodology the partners want to foster the implementation process of design guidelines based on international technology and knowledge transfer in Thailand.

In this paper a first approach of the structure of the methodology is introduced.

4.2 Terms and definitions of technology and knowledge transfer

The term "technology transfer" can be defined as the diffusion of technological knowledge inside an economic area or from an industrialised to a developing country (Woll, 2008). Another similar definition defines technology transfer as the transfer of technological knowledge (e.g. research and development results) for application in production process. Here technology transfer can be realised between universities, inventors, research units and companies, between multi national companies, between different companies, between industrial countries, between industrialised countries and developing countries (Brockhaus, 1998). Transfer of practical and educational knowledge is not part of technology transfer (Brockhaus, 1998) and can be identified as knowledge transfer.

Following the two definitions the term "technology transfer" can be regarded in the context of this paper as follows:

Technology transfer in the field of road traffic infrastructure is the transfer of technological knowledge (research results, available guidelines and best practice) for application in the design process of road infrastructure, including the adaptation to national and local specifics.

Technology transfer can be realised e.g. between universities, research units and further organisations from industrialised and developing/emerging countries.

Whereas knowledge transfer can be regarded in the context of this paper as follows:

Knowledge transfer can be defined as the exchange and transfer of practical and educational knowledge between universities, research units, organisations and further experts, stakeholders and interested persons e.g. in the design of road infrastructure or road traffic safety.

4.3 Design guidelines - status quo in Thailand and Europe

In European countries rules and regulations for the design of road infrastructure are normally defined in guidelines which are compulsory or partly recommendatory. If road and traffic engineers follow these rules and regulations, the design should have a high safety level.

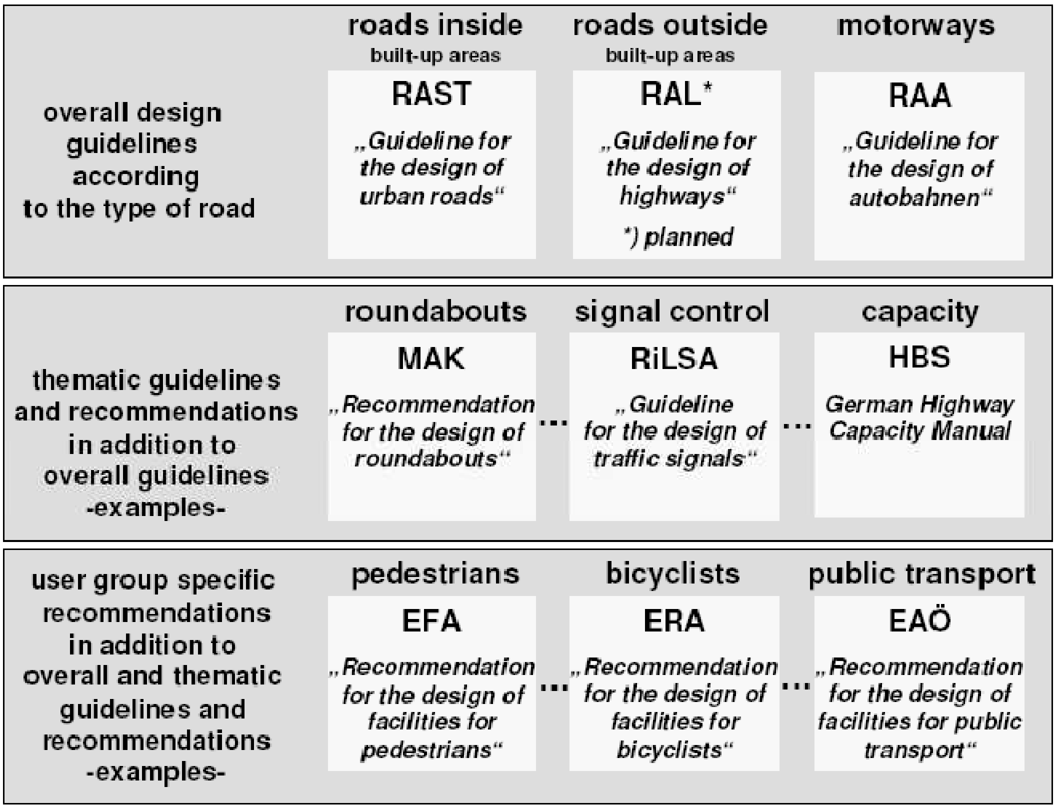

***Figure 4*. Structure of design guidelines used in the design of road infrastructure in Germany**
Source: Vesper (2009)

German and Hungarian road engineers have for instance access to various design guidelines and recommendations which cover nearly all aspects of the design of road infrastructure. The selection of respective guidelines and recommendations, which need to be considered in the German and Hungarian road engineers have for instance access to various design guidelines and recommendations which cover nearly all aspects of the design of road infrastructure. The selection of respective guidelines and recommendations, which need to be considered in the design process, depends mainly on the type of road, the subject of design and the affected road user groups by the planned road infrastructure. The structure of available German design guidelines is shown exemplarily in *Figure 4*.

Thai road engineers often have no such guidelines to follow because only a few national guidelines exist and relate to only a few topic areas. Even for topics where they are available, for most areas, no research based knowledge exists, which would adapt foreign guidelines or standards to national conditions. Instead of national guidelines, often guidelines from other countries like Japan, Australia or the United States are used and they are only available in foreign language and are not adapted to national conditions in Thailand. In many cases, road and traffic engineers, for lack of appropriate guidelines, have to design road infrastructure based only on individual decisions, assumptions or estimations which could be the reason for the inadequately designed roads especially from the point of road traffic safety.

Experiences of road safety audits and results of research projects executed by Thailand Accident Research Centre (TARC) confirm this statement. There is therefore an urgent need to develop Thai national guidelines for the design of road infrastructure in different topic areas in order to provide for Thai road and traffic engineers the research-based knowledge for the design of road infrastructure and traffic control.

4.4 Structure of Methodology

The “Methodology for design guideline implementation based on international technology and knowledge transfer” comprises different working phases with involvement of institutions, organisations and target groups which belong to different knowledge-levels. The structure of methodology is shown in *Figure 5*.

The **first part of the methodology is the technology transfer** of available design technologies from Europe to Thailand. Here design methods will be exchanged between international research organisations and institutions on the same knowledge level (horizontal transfer). Based on the results of the activity “exchange”, the transferred design technologies need to be adapted to national conditions. With adaptation one considers differences of behavioural aspects of road users as well as general aspects in the design like right/ left-hand driving, traffic signs or traffic rules in the design guidelines. In general one should consider that it depends on the specific subject, method or parameter of design technology, whether it needs to be adapted to national conditions or not. Here the spectrum of adaptation is in between the range of no adaptation up to full adaptation. Beside engineering aspects the adapted knowledge should meet requirements of the target groups “scientific institutions, associations and committees”, “universities and technical colleges” and “engineers and practitioners”. Here especially the scope and the preparation of knowledge should meet the respective requirements.

The adapted design technologies are ready for implementation in the **second part of the methodology – the knowledge transfer**. The main objective of this part is the knowledge transfer of generated and adapted knowledge from research level to lower knowledge levels like education, user and impact level (vertical transfer). Diffusion of knowledge can be realised amongst others by publications, campaigning, training and education as shown exemplarily in *Figure 5*. The diffusion of knowledge is an essential part of the proposed methodology because it makes the knowledge available for target groups in practice. Improvement of road traffic safety can only be achieved if the generated knowledge achieves the target groups and will be applied in practice.

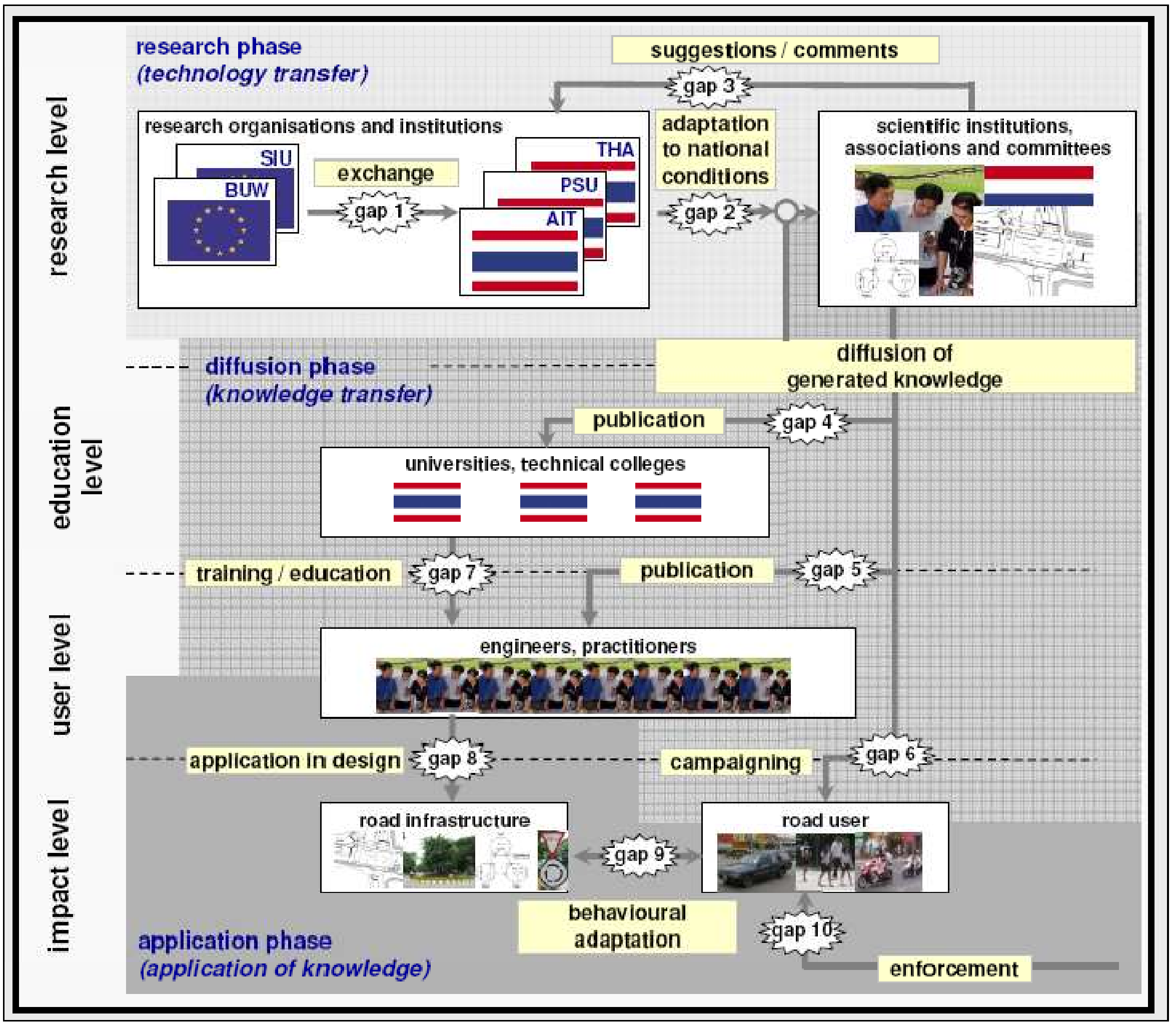

***Figure 5*. Structure of methodology for design guideline implementation**
Source: Vesper (2009)

The **third part of the methodology – the application of knowledge** - comprises the application of generated knowledge in the design of road infrastructure as well as in the use of road infrastructure by road users in practice. Here new design methods need to show their impact on road traffic safety. Further measures, like enforcement can contribute to behavioural changes of road users and can contribute to higher acceptance of new design methods.

4.5 Target groups

In order to implement the design guidelines successfully, several target groups need to be addressed. The design guidelines should meet amongst others the requirements of the following target groups:

- universities and technical colleges (multiplicators of generated knowledge on education level),
- engineers and practitioners (users of generated knowledge on user level),
- road users which belong to different user groups (beneficiaries of generated knowledge on impact level),

- scientific institutions, associations and committees for these purposes (promoting the process of design guideline implementation).

Institutions and organisations that are responsible for legal implementation of design guidelines as well as for the process of legal guideline implementation are not considered in this paper because this process differs in each country significantly. In this paper the legal implementation is mainly regarded as a parallel process. For this reason it is not mentioned in *Figure 5*.

4.6 Acceptance gaps in methodology

The methodology of design guideline implementation can be subdivided in different phases. Here one can distinguish between the research, diffusion and application phase. In each phase several institutions, organisations or person-groups from the same or different knowledge levels are involved in the process. Subject of each implementation phase are one or more specific activities which will be realised during the phase. The chronological order of activities depends on the phase considered and can be conducted in general alternatively one after another or simultaneously, as shown in *Figure 5*.

As mentioned above, different parties (institutions, organisations or person groups) are involved in the implementation process and in this way they are involved also in the activities of the three implementation phases. The involved parties have often different characteristics (like objectives, requirements, behaviour …), which can lead to acceptance gaps (gap 1 to gap 10) in the process of design guideline implementation (see *Figure 5*). In consequence of this fact, one main pre-condition of a successful “design-guideline implementation” is the overcoming of the mentioned acceptance gaps during the application of the methodology. In *Table 2* and *3* typical issues or respective problems are listed exemplarily which could be the subject of acceptance gaps.

***Table 2*. Acceptance gaps in the methodology for design guideline implementation (part A)**

phase	activity	selected issues/problems which could be subject of acceptance gaps
research phase	exchange	- determination of the subject of technology transfer, - selection of appropriate methods and measures for technology transfer.
	adaption to national conditions	- differentiation of methods and parameters, which can be / should be adapted or not (wide spectrum from no adaptation to full adaptation to national conditions, depending on considered methods and parameters), - adaptation of guideline structure and content according to requirements of target groups, - consideration of behavioural aspects of road users in adaptation process.

***Table 3*. Acceptance gaps in the methodology for design guideline implementation (part B)**

phase	activity	selected issues/problems which could be subject of acceptance gaps
diffusion	publication	- way of guideline provision for target groups, - language of publication, - missing recognition for need of new guidelines.
	campaigning	- missing understanding of rules and function of new design methods / measures by road users, - behavioural opposites to new design methods / measures.
	trainning/education	- need for consideration of new design methods and measures in lectures and training courses, - readiness to adapt content of current lectures and training courses, - provision of training and pre-training courses to target groups.
application	application in design	- availability of new design methods for target groups, - practicability of new design methods, - comprehensibility of new design methods, - recognition by public authority, awarding authority, etc.
	behavioural adaptation	- impact of new infrastructure design on behaviour of road user (physical and mental impact of new design method on road user), - impact on workload of road user (cf. Fuller, 2005).
	enforcement	- necessity of compulsory measures to influence behaviour of road users, - general effectiveness of enforcement measures.

4.7 Application of methodology

In the framework of the Thai-E.C. project "Improving Road Traffic Safety in Thailand – A Common Challenge for European and Thai Universities" the proposed methodology for design guideline implementation will be practically tested by the implementation of two design guidelines in Thailand.

Here one design guideline will deal with the "Design of traffic control at signalised intersections" and a second one with the "Design of roundabouts" in Thailand.

The outlines of the two guidelines are introduced by Vesper et al. (2010) and Koren et al. (2010) in more detail.

5. FORECAST

It is acknowledged that the design of road infrastructure has a strong influence on road traffic safety. According to Treat (1977) more than 40% of accidents are influenced by the element "Environment" which comprises road infrastructure.

Several studies (Brilon, 2008, FHWA, 2000, Elvik et al., 2009) have shown that proven design methods and measures – e.g. with the view on road traffic safety - can be transferred successfully from one country to another.

The new approach to developing a methodology for design guideline implementation gives an overview of the implementation process of design guidelines based on international technology and knowledge transfer. The methodology will foster the implementation of design guidelines and the application of research based knowledge in the design process of road infrastructure.

The authors are convinced that the guideline implementation and the associated design of safer road infrastructure will be a main measure to improve road traffic safety and to counteract the current road traffic safety situation especially in emerging and developing countries in the future.

6. ACKNOWLEDGEMENTS

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THAILAND DEPARTMENT OF HIGHWAYS' ROADSIDE SAFETY STRATEGIC PLAN 2009-2013

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Abstract: Road accidents in Thailand kill some 13,000 people annually. The cost to the nation has been calculated at around 243,000 Million Baht or about 2.8 % of the gross domestic product in 2008 value (DOH Study of traffic accident costs in Thailand, 2007). A significant number of deaths, some 8% occur on the highways under the jurisdiction of the Department of Highways (DOH). Of all the crashes on the highways, run-off-the road or roadside crashes constitute the majority. In 2007, there were 5,837 roadside crashes or 43%, resulting in 586 deaths or 34% of all DOH's highways' deaths (DOH Annual accident statistics, 2008). Of these, the most critical crashes are those involving vehicles crashing into roadside trees. These events have resulted in an estimated 234 deaths.

This paper describes the strategic plan for improvement of roadside safety. It highlights the magnitude of the roadside crash problem, its causes, the goal to be achieved and the strategies with the actions to achieve the goal together with and an example of a case study.

Key Words: Road accidents, traffic accident costs, roadside safety, roadside crash problem

1. INTRODUCTION

Road accidents in Thailand kill some 13,000 people annually. The cost to the nation has been calculated at around 243,000 Million Baht or about 2.8 % of the gross domestic product in 2008 value (DOH's Study of traffic accident costs in Thailand, 2007). Although most of the fatalities, around 70 per cent involve people using motorcycles, a significant number of deaths, some 8% occur on DOH highways. Of all the crashes on the highways, run-off-the road or roadside crashes constitute the majority. In 2007, there were 5,837 roadside crashes or 43%, resulting in 586 deaths or 34%. Of these, the most critical crashes are those involving vehicles crashing into roadside trees. These events have resulted in an estimated 234 deaths.

This strategic plan for improvement of roadside safety sets out the magnitude of the roadside crash problem, its causes, the goal to be achieved and the strategies with the actions to achieve the goal together with and an example of a case study.

1.1 The Principle

Drivers will continue to make mistakes and have accidents on our highways. They should not have to pay for their mistakes with their lives. The Department of Highways can and must further improve the highways and roadside to prevent roadside crashes, but in the inevitable event of a crash, DOH will ensure that the severity of impact to occupants of the errant vehicle is significantly reduced.

1.2 The Vision

A highway system that prevents drivers from running off the roadway and protects errant vehicle occupants from death or serious injury.

2. THE ROADSIDE SAFETY PROBLEM

Each year, some 13,000 people die from road accidents on Thai roads. While the majority of the deaths involve people using motorcycles and occur on roads other than the national highways under the jurisdiction of DOH, a significant of these deaths and serious injuries involving cars and pick up trucks happen on the DOH highways. For the year 2007, the number of roadside crashes on DOH highways was 5,837 or 43% of all crashes. These result in 586 deaths and estimated 8,028 serious injuries and 29,827 minor injuries. Using the figure from the DOH study on traffic accident cost, these casualties amount to a loss to the nation of some 8,202 Million Baht in 2008 value.

3. THE CAUSE

It is well accepted that road accidents occur as a chain of event. Each element, the human errors, infrastructure defects and vehicle defects often forms part of this chain. The limited TARC study has shown that human errors constitute the majority of the cause of a crash, some 89 %. The Venn diagram in Figure 1 shows percentages of each element. The majority of human errors are from inappropriate behaviours, eg. speeding, dangerous overtaking. This type of behaviour, in many instances, stems from the current inadequate drivers' training and licensing system. The lack of adequate knowledge about traffic rules and regulations can result in and has led to poor decision making that resulted in a fatal crash. In many of TARC in-depth crash investigations, drowsiness resulting from fatigue was also found to be a main contributing factor to crashes.

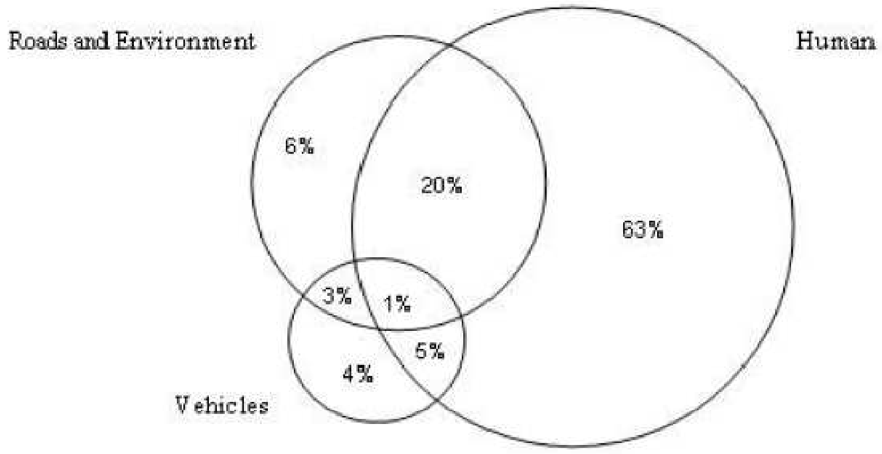

Figure 1. The three elements in an accident chain of events

4. THE GOAL

Given the experience and expertise of the DOH staff which comprise administrators, chief engineers, senior engineers and engineers and supporting technical and administrative staff, it is reasonable to set the goal of the strategic plan as: reduce the number of roadside crashes by 50%, from the current 5,837 to 2,918 and the number of deaths and serious injuries by 75% from the current 586 deaths to 147 deaths in 2013.

5. THE STRATEGIES

The following 5 strategies are necessary for reaching the stated goal. Each strategy has its own objectives and requires actions to achieve its objectives. Table 1 lists the objectives, strategies and the required actions.

Strategy 1 Increase the awareness of roadside safety.

Strategy 2 Increase knowledge on the cause, location, mechanism, the costs and effective treatments of roadside crashes.

Strategy 3 Prevent vehicles from running off the highway.

Strategy 4 Protect errant vehicles from hitting roadside objects or rollover.

Strategy 5 Reduce severity of crash impact to occupants of errant vehicles

Table 1. Strategies objectives and actions for improvement of roadside safety

Strategic Objectives	Strategies	Actions
Increased awareness of the importance of roadside safety by the public (road users, citizens, decision makers, police, and special interest groups (e.g. Thai Health Promotion Office, Foundation for Protection of Consumers)	Increase the awareness of roadside safety	• Set up a steering committee to oversee the implementation of the strategic plan • Invite key partners and stakeholders to join the steering committee , including members from the media • Develop public awareness materials and programs on roadside safety for distribution within DOH, consultants, partner organizations and general public. • Conduct meetings, and workshops to highlight roadside safety issues. • Estimate the budget required for roadside safety and prioritize the use the budget.
Comprehensive roadside safety information resources including crash characteristics, research findings, highway inventories, traffic data. On-going project to conduct safety analyses and identify hazardous roadside locations.	Increase knowledge on the cause, location, mechanism, the costs and effective treatments of roadside crashes.	• Systematically identify and analyze hazardous or potentially hazardous roadside locations. • Increase the use of road safety audits. • Develop in-depth crash database for specific roadside issues. • Develop a database of unreported roadside crashes to support research on crash severity • Request generic information from insurance companies on property damage only (PDO) rashes. • Investigate and monitor the effectiveness of roadside, treatments. • Develop improved modeling of occupant injury severity in runoff- road crashes (e.g., by speed of impact, age of occupant) • Improve predictive models to study the impacts of changes in conditions or policy (e.g., speed limit changes, new barrier system) on roadside safety. • Calculate and update societal costs from roadside crashes
Improved highway designs that reduce the probability of vehicles running off the road.	Prevent vehicles from running off the highway	• Initiate educational efforts to raise the awareness of roadside safety issue to the DOH design engineers and executives, and politicians • Stress the importance of providing clear zone in the design of highways • Highlight effects of highway geometric design on roadside safety (e.g., sight distance, curvature)

Strategic Objectives	Strategies	Actions
		• Promote the importance of consistent designs that conform to driver expectancy. • Incorporate road safety audits in the highway design and construction process • Use road safety audit process to identify and improve geometry of existing and hazardous highway sections • Establish a process for periodic review and updating of design documents to reflect new knowledge and research. • Develop training materials for highway designers, contractors and maintain workers that emphasize the relationships between roadway design and safety • Develop guidelines for use of rumble strips and edge-line rumble markings • Improve signing, lighting, and delineation of the roadway for all conditions including heavy rains • Improve skid resistance at curve sections • Prevent occurrence of water on road surface through proper and prompt maintenance of road surface defect. • Educate drivers of the risks of ROR associated with excessive speed. • Educate drivers of the often fatal consequence of ROR crashes in work zone. • Educate drivers of the risks of ROR associated with vehicular malfunctions. • Devise effective speed enforcement strategies that promote safer driving behavior.
Improved roadside treatments that reduce the number of collisions with hazardous objects along the roadside. Improved highway geometrics and roadside designs that reduce the probability of rollovers.	Protect errant vehicles from hitting roadside objects or rollover	• Identify and remove or shield off trees planted in clear zones of hazardous highway sections or potentially hazardous sections. • Initiate a program to systematically shield off existing trees, utility poles and other hazardous roadside objects • Review the adequacy of existing length of the barrier required for proper protection of errant vehicles from hitting poles. This length should be computed using the expression given in AASHTO document 2002 • Discontinue the use of the use of “turned-down guardrail terminal” and “sloped concrete end treatment” on high-speed high volume

Strategic Objectives	Strategies	Actions
		highways. • Review the use of concrete curbs on high speed highways as it was found to have caused vehicle to fly. • Review existing practice of tree planting in clear zone with the objective of removing young and small trees • Develop and implement a guidelines for highway landscaping that ensures that planting of trees if necessary is well outside of the clear zone • Check if the design embankment height and its side slope meet the safety criteria, if not, provision of proper barrier must be specified. • Research and develop design standards for curbs, gutters, slopes and ditches that allow errant vehicles to traverse these features without overturning. • Review the current practice of road construction methods with a view to improve safety of the traveling public in work zone • Continue educational efforts to raise the awareness of roadside safety issue to the DOH design engineers and executives, and politicians • Educate the public about the hazards of trees close to the roadway.
Improved roadside safety hardware. Improved vehicle compatibility and crashworthiness relative to roadside features. Increased seat belt usage and effectiveness of occupant protection systems.	Reduce severity of crash impact to occupants of errant vehicles	• Initiate a procedure to inspect and promptly repair damaged guardrails • Replace the existing robust kilometer posts with 'forgiving ' posts • Conduct research and develop new ' forgiving' sign supports and guided posts • In the short term, upgrade the 81.0 cm. New Jersey concrete barriers currently installed in areas where the risk of having heavy vehicle accident is high to a rigid+ flexible system (Type 4 concrete barrier in AASHTO 2002) with the total height of 127.0 cm. • In the long term, research into the crashworthiness of the existing guardrails and terminals and concrete barriers (NOTE THIS POINT WAS MOVED FROM STRATEGY 4) • In the short term, install the basic type of crash cushions, the sand filled plastic barrel at gore areas and monitor its performance

Strategic Objectives	Strategies	Actions
		• For the long term, conduct research on the effectiveness of various types of crash cushions
		• Educate the public on the importance of using seat belts • Educate highway police on the importance of enforcing the use of seatbelt

6. EXAMPLE OF A CASE STUDY

This section describes an example of what can be done to improve roadside safety. The case given concerns roadside crashes on Highway number 414 (Lopburiramesh road) linking the city of Hat Yai and Songkhla, a distance of 24 km. Figure 2 shows location of the highway and Figure 3 shows a typical roadside crash with vehicle hitting a roadside tree.

6.1 Roadside crashes statistics during 2005-2008 (to June)

59 fatalities or average 17 cases/year
89 serious injuries or average 25 cases/year

6.2 Estimate of economic loss from casualties per year

From fatalities 17 x 5.62 = 95.54 million Baht

From serious injuries 25 x 0.24 = 6.0 million Baht
Total = 101.54 million Baht

This estimate does not include other costs such as cost of repair to damaged vehicles and medical treatment cost of minor injuries.

6.3 Estimated cost of installation of guardrail

At 1600 baht per metre , the 24 km length of guardrail on both sides of median
24 x 2x 1.6 = 76.8 million Baht

From the estimates, it is clear that the benefit of guardrail installation is that it can likely save lives and prevent serious injuries resulting from errant vehicles hitting roadside trees. This amounts to 101.54 million Baht per year while the guardrail installation on both sides of the median costs only 76.8 million Baht.

Figure 2 Location of Highway 414 in Songkhla province

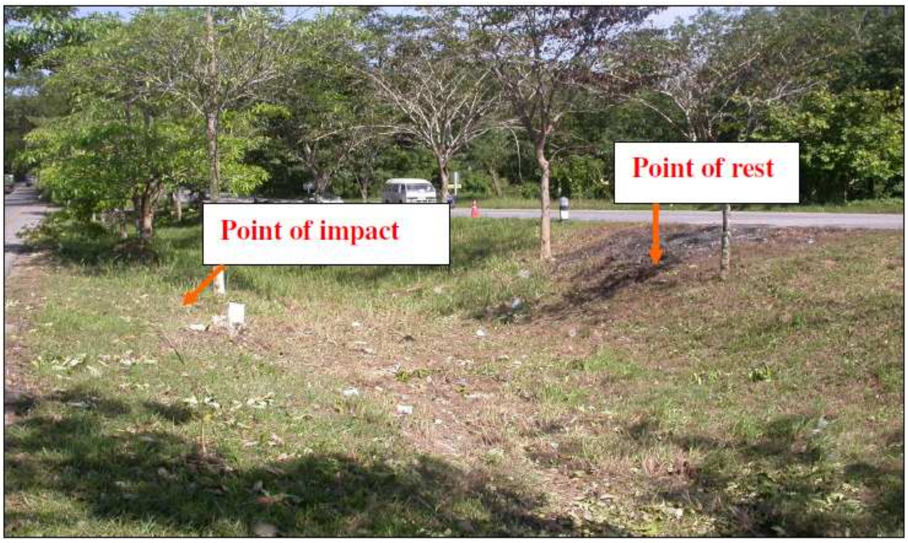

Figure 3. A Typical crash site on median of Highway 414 where an errant vehicle hit a tree and caught fire

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8. REFERENCES

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