Potentials for Modal Shift towards Bus Rapid Transit (BRT) in an Asian Developing City

Thaned SATIENNAM [a], Sittha JAENSIRISAK [b], Wichuda SATIENNAM [c], Sumet DETDAMRONG [d]

[a,c,d] *Sustainable Infrastructure Research and Development Center, Department of Civil Engineering, Faculty of Engineering, Khon Kaen University, 40002, Thailand*
[b] *Department of Civil Engineering, Faculty of Engineering, Ubon Ratchathani University, 34190, Thailand*
[a] *E-mail: sthaned@kku.ac.th*
[b] *E-mail: sittha.j@ubu.ac.th*
[c] *E-mail: wichsa@kku.ac.th*
[d] *E-mail: sumet@kkumail.com*

Abstract: Many Asian developing cities consider Bus Rapid Transit (BRT) system in their public transport planning because of its advantages on lower investment cost and flexible implementation over rail systems. The objective of this research is to assess potentials of BRT for shifting travellers from private vehicles. Three different BRT systems were designed for the main corridor pass through Khon Kaen City, in Thailand. The study developed modal split models for predicting the choices of private vehicle users on different BRT systems. The models were developed based on a Stated Preference (SP) survey. It was found that BRT could attract some motorists to change mode choice. However, majority of car users still prefer their own private vehicle. Apart from travel time and cost affecting the mode choice, some socio-economic factors, including gender, age and resident location, also influence the choice of BRT.

Keywords: Bus Rapid Transit, Stated Preference, Logit Model, Mode Choice, Private Vehicle User, Asian Developing City

1. INTRODUCTION

Many Asian developing cities consider Bus Rapid Transit (BRT) in their public transport planning because of its advantages on lower investment cost and flexible implementation over rail systems (Jaensirisak and Klungboonkrong, 2009). However, to implement the BRT project successfully, there are several urban characteristics of Asian developing cities, which should be carefully considered; for example, urban sprawl (caused by the poor city planning) and high private vehicle usage (due to the poor existing public transport).

There are many previous studies proposing integrated strategies with BRT systems to cope with urban sprawl (Satiennam et al., 2006, 2007a, and 2007b). Due to the poor service of existing public transports and cheap motorcycle use, many Asian developing cities have very high private vehicle share especially the motorcycle. Hanoi and Ho Chi Minh cities in Vietnam have recorded motorcycle share of 81%, and 90%, respectively, of all motorized trips (Schipper et al., 2005; JICA et al., 2004). In many cities in Thailand, the motorcycle share accounts for approximately a half of all travel trips, e.g. 51% of all trips in Khon Kaen City (SIRDC, 2008). Thus, it is very challenging to encourage modal shift from motorcycle to BRT. Previously, there are studies (Arasan and Vedagiri, 2011; Satiennam et al., 2011) that proposed policies and planning of bus systems in a motorcycle-dominated communities.

Furthermore, it is very interesting to study planning of BRT in developing cities with high passenger car (PC) and motorcycle (MC) share. Some passenger car users from high income families prefer their existing mode because of comfort, privacy and status consideration. It is very difficult to shift them to use the public transport even if high efficient public transit is provided. Besides, most motorcycle users from low and middle income families do not mind less privacy. Plus, motorcycle use is cheap and provides high accessibility even though it is unsafe and uncomfortable. While the BRT in Jakarta initiatively operated in year 2004, only 20% of BRT riders have switched from private motorized modes (Ernst, 2005). There is a lack of previous research studying about a comparison of BRT choice between passenger car users and motorcycle users as well as a comparison of choice proportion among different type of BRT systems.

Therefore, the objective of this research is to assess potentials of BRT in shifting travellers from private vehicles. Three different BRT systems were designed for the main corridor pass through Khon Kaen City, in Thailand. The study developed modal split models for predicting the choices of private vehicle users on different BRT systems. The models were developed based on a Stated Preference (SP) survey. The study also compared socio-economic characteristics, elasticities, values of time between the motorcycle and passenger car users as well as the operating strategy of BRT that influences the motorcycle and passenger car users.

The content of this paper is separated into follow sessions. The second part describes the research methodology. The third part displays the results and discussions. The fourth part presents the application of developed models for BRT planning through a case study, and the final part gives the conclusions and recommendations of this research.

2. RESEARCH METHODOLOGY

2.1 Case Study

Khon Kaen City in Thailand was selected as a case study of an Asian developing city because it is a private vehicle-dominated city similar to many developing cities in Asia. Khon Kaen City has 81% of all travelling trips by private modes (51% by MC and 30% by PC) (SIRDC, 2008). Less than 20% of all trips is by Song Thaew (the existing public pickup truck). The existing Song Thaew is not popular because of poorly designed service routes, delayed and unpunctual service, uncomfortable and unsafe vehicle and driving.

Khon Kaen city currently has a plan to operate BRT system along its main corridor (called the Friendship Highway) passing though the middle of Khon Kaen City. The BRT line on this corridor is called the Red Line, aligning from the North to the South of the City. This Red Line is the first phase among total five lines of the full stage of BRT planning in Khon Kaen City. The Red Line has 17 stations along its 30 km corridor as displayed in Figure 1.

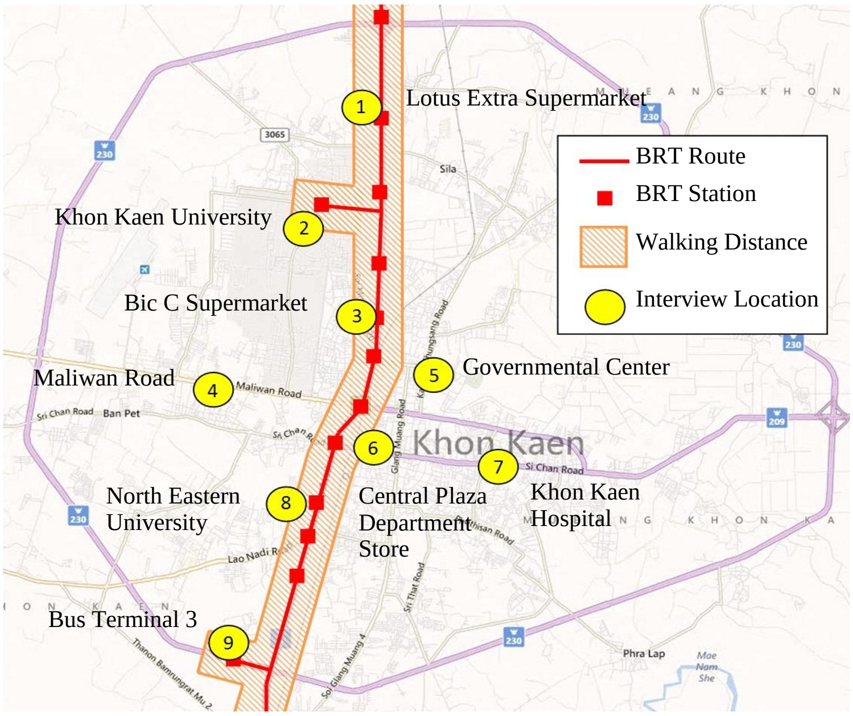


Figure 1. Bus Rapid Transit planning corridor and interview location in Khon Kaen City

2.2 Design of Bus Rapid Transit System

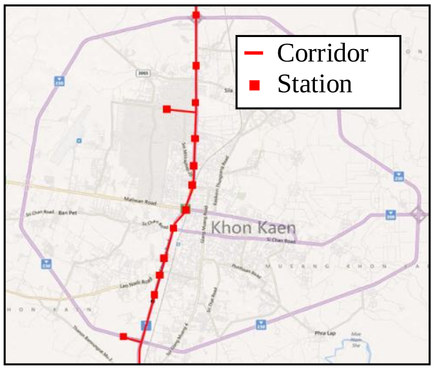
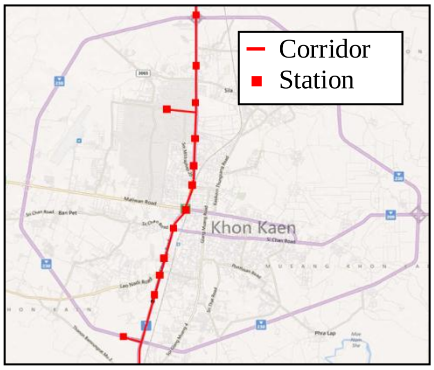
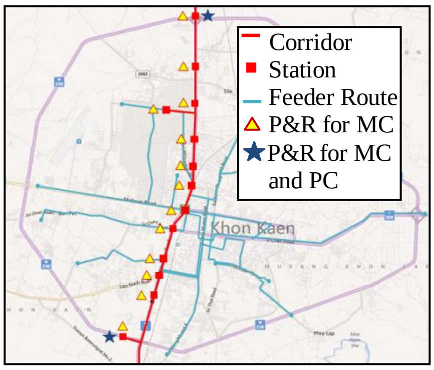
To explore the efficiency of BRT system influencing the choice of private vehicle users, this study designed a few different BRT systems with different efficiency levels to propose to private vehicle users. The design concept is to propose the BRT systems suitable with the conditions of Asian developing cities where have limited investment budget, urban sprawl and high private vehicle usage. The three different BRT systems are:

1) The minibus (MNB): the small air-conditioned bus is operating along mixed traffic lane. This system provides bus stops along the service route. This system is proposed for Asian developing cities that have limited investment budget. Mainly, the uncomforted vehicle of the existing public transport is improved to attract some of private vehicle users to use MNB
2) The BRT without P&R and feeder (BRT): the BRT is operating along the exclusive bus lane. This system provides stations along its service corridor. The bus priority system is provided at signalized intersections. This system is proposed for Asian developing cities that need rapid public transport with investment cost much lower than a rail transit. The investment cost is mainly for upgrading vehicles and constructing exclusive bus lanes, stations with elevated platforms, and bus priority system with signalized intersection.
3) The BRT with P&R and feeder (BRTS): the BRT is operating along the exclusive bus lane. The bus priority system is provided at signalized intersections. In addition, this system provides the P&R for MC at every station and P&R for PC at end-of-line stations. Song Thaew service is re-routed as a feeder system free of charge. This system is proposed for Asian developing cities that have existing public transport routes that can be re-routed being a feeder system for BRT. A significant number of private vehicle users, whose trip origins/destinations far away from BRT corridor, can be shifted to use BRT by providing P&R at BRT stations. The additional investment cost is necessary for providing P&R facilities at BRT

stations, as well as good integrated system and management."

The summary of the proposal of different systems of BRT is displayed in Table 1. The illustrative images of P&R for motorcycle and Song Thaew route feeder at stations are displayed in Figure 2. The service time of all systems starts from 6:00 AM to 12:00 PM.

Table 1. Summary of proposed different systems of Bus Rapid Transit

System	Vehicle Type	Busway, Station & Priority	Service Network
MNB	 - Capacity 21-40 per. - Speed 25 kph - NGV	 - Mixed traffic lane - Bus stops	
BRT	 - Capacity 60-80 per. - Speed 40 kph - NGV	 - Exclusive bus lane - Stations with elevated platforms - Bus priority system at signalized intersection	
BRTS	 - Capacity 60-80 per. - Speed 40 kph - NGV	 - Exclusive bus lane - Stations with elevated platform - Bus priority system at signalized intersection - P&R for MC at stations - P&R for MC and PC at end-of-line stations - Song Thaew feeder routes	

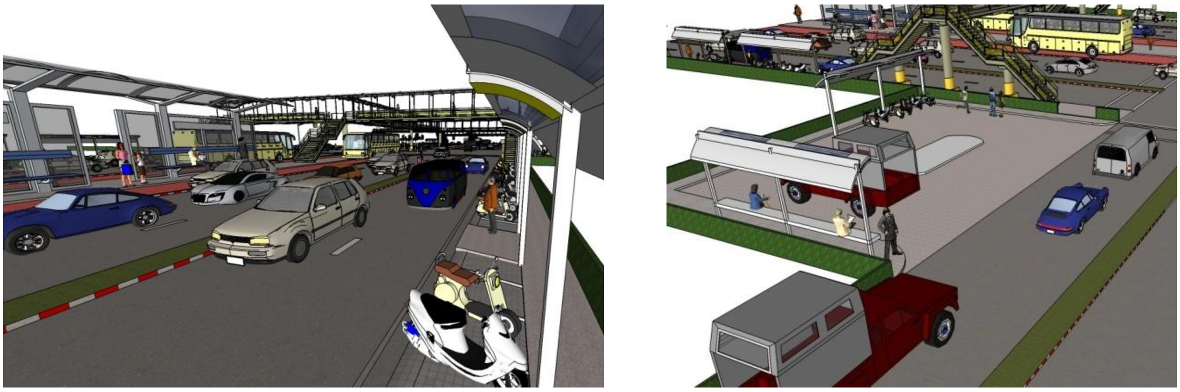


Figure 2. P&R for Motorcycle and Song Thaew Route Feeder at Bus Rapid Transit Station

2.3 Target Group

This study explores the choice of BRT systems for private vehicle users traveling along the Friendship Highway by all trip purposes. The private vehicle users were classified into two groups, namely, a group of motorcycle users and a group of private car users. The number of interviewed samplers totalled 600 in according with a recommended range of 200-500 samplers for an analysis of disaggregate model (Richards and Ben-Akiva, 1975), with 300 samplers in each group of private vehicle users.

2.4 Survey Method

This study applied the Stated Preference (SP) Method that assumes the BRT is operating along the Red Line along Friendship Highway at Khon Kaen City. The SP questionnaire survey was conducted. The interview survey was conducted at many trip generating locations, including universities, bus terminal, department stores, and supermarkets, along the BRT corridor. The nine survey locations are shown in Figure 1. The sample was interviewed individually. To avoid confusion of sample, one sample was presented by only four SP questions of different assuming service conditions of one system of BRT. The 200 samples were interviewed by one proposing system of BRT, divided into 100 passenger car users and 100 motorcycle users. In conclusion, 600 samples were interviewed for 3 different systems of BRT.

2.5 Development of the SP experiment

This study determined the service attributes of the BRT that influence choice decision of travelers. The selected service attributes include:

1) Access time between residential location and BRT station:
    - When a motorcycle user reaches a station, he/she can park the motorcycle at P&R area near the station. This access time is 1 min. for the traveler whose residential location is within 400 m. from the station. The access time is 2 min. for travelers whose residential location is further than 400 m.
    - For a passenger car user to reach a station (since there is no P&R for PC at station inside the city, a traveler whose residential location is within 400 m. from the station has to walk to the station for 6 min. (The walking speed is 4 km/hr). Travelers whose residential location is further than 400 m. can access the station by Song Thaew feeder for 9 min. For travelers staying outside the city, they can park their passenger cars at P&R area of the station. The access

time is 0.5 min. for the travelers whose residential location is within 400 m. from the station and 1 min. for travelers whose residential location is further than 400 m. from the station.

2) Waiting time at station: this study decided the waiting time at station similar to the frequency of existing Song Thaew service, every 10 min. To study a variation of waiting time influencing BRT choice, the SP exercise set three levels of the waiting time: 2, 6, and 10 min.
3) In-vehicle travel time of BRT: it depends on the operating speed of different proposed system. The average speed of minibus (MNB) was determined at 25 km/hr similar to the surveyed average speed of Song Thaew currently operating along the same corridor. The average speed of BRT was determined at 40 km/hr according to the average speed of BRT systems in many cities (Barr et. al., 2010). These average speeds were further applied to calculate the in-vehicle travel time of BRT. The stopping time at station was determined to be 10 sec.
4) Egress time between BRT station and destination: this study surveyed average walking time of travelers. The survey found that average walking time was 1 min.
5) Total travel time: the total travel time was the combination of all travel times between traveler's residential locations and their destinations, including access time, waiting time, in-vehicle travel time, and egress time.
6) Ticket Fare of BRT: this study decided the ticket fare of BRT should be close to the existing ticket fare of Song Thaew (9 Baht/trip). To study a variation of travel cost influencing BRT choice, the SP exercise set three levels of the ticket fare: 5, 10 and 15 Baht/trip.

Therefore, in the SP exercise, two attributes including waiting time and ticket fare were set at three levels. Nine service scenarios were set as shown in Table 2. Other service attributes input in the model analysis were based on existing situation of each respondent.

Table 2. Assumed situations of services of bus rapid transit in Khon Kaen City

Scenario	Waiting Time (Min.)	Fare (Baht[1])
1	2	5
2	2	10
3	2	15
4	6	5
5	6	10
6	6	15
7	10	5
8	10	10
9	10	15

1 USD ≈ 30 Baht in 2012

2.6 Survey of Service Condition of Private Vehicles

This study determined the service attributes of private vehicles that included travel time and travel cost. The travel times of motorcycle (TTMC) and passenger car (TTPC) were surveyed by driving motorcycle and passenger car along the BRT corridor, simultaneously recording travel time by stop watch. Average speed of motorcycles and passenger cars were 45 and 60 km/hr, respectively. The travel costs of motorcycle (CMC) and passenger car (CPC) were the gasoline cost that could be calculated from questionnaire data.

2.7 Mode Choice Model Development

This study developed the mode choice model by applying the Random Utility Theory using 80% of all questionnaire data. The Binary Logit model was applied to analyze the mode choice data from the SP exercise. The Binary Logit function is displayed as Equation 1 (Ben-Akiva and Lerman, 1985).

$$P_n(i) = \frac{e^{V_{in}}}{e^{V_{in}} + e^{V_{jn}}} \quad (1)$$

Where

$P_n(i)$ = Probability of traveler n choose mode i
V_{in} = Systematic components of utility of traveler n choosing mode i
i, j = Travel mode i and j

This study considered many service attributes, listed in Table 3, which may influence mode choice. Those considered service attributes were selected from previous studies (Jaensirisak, 2005; Limanond et al., 2010). Besides the service attributes, this study also considered socio-economic characteristics of travelers, such as gender, age, income, as well as residential location of travelers, in the utility function.

Table 3. Independent variables in utility function

Variables	Meaning
SEX	Dummy variable of gender of traveler (0:Male and 1:Female)
AGE	Dummy variable of age of traveler (0: ≤ 30 year old and 1: > 30 years old)
AREA	Residential location ()0:within 400 m radius from BRT station, 1:outside 400 m radius from BRT station)
INC	Income of traveler (0: ≤ 20,000 Baht and 1: > 20,000 Baht)
LICENSE	Dummy variable of holding of driving license (0:no driving license and 1:holding of driving license)
CONSTANT	Constant term of BRT utility
TTMNB, TTBRT, TTBRTS	Total travel time of MNB, BRT, and BRTS (min.)
CMNB, CBRT, CBRTS	Total travel cost of MNB, BRT, and BRTS (Baht)
TTMC, TTPC	Total travel time of MC and PC (min.)
CMC, CPC	Total travel cost of MC and PC (Baht)

The correlation between independent variables in the utility function was removed by checking the Coefficient of Correlation between variables. One of the related variables, in which R was higher than 0.5, were removed. The Coefficients of Correlation between independent variables of motorcycle and passenger car users are presented in Table 4 and 5.

Table 4. Coefficient of Correlation among independent variables of motorcycle users

	SEX	AGE	AREA	INC	LICENSE
SEX	1				
AGE	-0.06[1], 0.13[2], 0.12[3]	1			
AREA	-0.12[1], -0.07[2], -0.31[3]	-0.15[1], -0.02[2], -0.18[3]	1		
INC	0.00[1], -0.05[2], -0.07[3]	0.44[1], 0.36[2], 0.50[3]	0.07[1], -0.09[2], -0.10[3]	1	
LICENSE	-0.15[1], -0.19[2], -0.22[3]	0.10[1], 0.16[2], 0.03[3]	-0.12[1], 0.05[2], 0.29[3]	0.23[1], -0.24[2], -0.07[3]	1

Remark: 1) A group of travelers proposed by MNB[1], BRT[2], and BRTS[3]
2) Variables with Correlation Coefficient higher than 0.5 are excluded from the model

Table 5. Coefficient of Correlation among independent variables of passenger car users

	SEX	AGE	AREA	INC	LICENSE
SEX	1				
AGE	-0.26[1], 0.05[2], -0.03[3]	1			
AREA	-0.07[1], -0.27[2], -0.14[3]	-0.04[1], -0.03[2], -0.14[3]	1		
INC	-0.29[1], 0.02[2], -0.12[3]	0.63[1], 0.54[2], 0.50[3]	0.03[1], 0.06[2], 0.10[3]	1	
LICENSE	-0.08[1], -0.04[2], -0.19[3]	0.38[1], -0.09[2], 0.43[3]	-0.02[1], 0.04[2], -0.12[3]	0.39[1], -0.05[2], 0.41[3]	1

Remark: 1) A group of travelers proposed by MNB[1], BRT[2], and BRTS[3]
2) Variables with Correlation Coefficient higher than 0.5 are excluded from the model

2.8 Model Validation and Selection

2.8.1 Internal validation

We conducted the internal validation by checking 2 following matters.

1) Sign of coefficients of independent variables: for example, a coefficient with negative sign means that the utility to travel by that mode decreases if the variable has a higher value.
2) t-value: If the t-value of an independent variable is higher than 1.96, it means that the variable influence mode choice has a 95% confidence level.

2.8.2 External validation

This study selected the method of Percent Correctly Estimated for external validation. Its equation is displayed as Equation 2.

$$\%\,\text{Correct} = \frac{\sum_{n=1}^{N} W_n}{N} \tag{2}$$

Where

$$W_n = \begin{cases} 1 \text{ if traveler n chose i once modeling result is } P_n(i) > 0.5 \\ 0 \text{ if else} \end{cases}$$

The principle of Percent Correctly Estimated is to calculate the percentage of accuracy of mode choice forecasting. The remaining questionnaire data (20% of all data from questionnaire, N) was used to forecast the mode choice through the developed mode choice model. The mode choice resulted from developed model was compared with the existing mode choice from questionnaire. For example, the traveler n chose i from questionnaire while the developed model results that traveler n has a probability more than 50% to choose mode i ($P_n(i) > 0.5$), thus $W_n = 1$; if it is not, $W_n = 0$. The % Correct is approaching to 100%, it means the developed model yields the forecasting mode choice closing to existing mode choice from the questionnaire.

2.9 Model Selection

The two steps of model selection procedure are shown as below.

1) Comparison among the developed models that have the same number of independent variables with the Likelihood Ratio Index (ρ^2). Likelihood Ratio Index, ρ^2 interprets how accuracy the model can forecast the mode choice behavior. It checks if ρ^2 approaches 1 and the developed model provides a high correlation among dependant and independent variables (Ben-Akiva and Lerman, 1985). The Likelihood Ratio Index, ρ^2 can be calculated by Equation 3. Subsequently, the model with higher Likelihood Ratio Index, ρ^2 is more appropriate.

$$\rho^2 = 1 - \frac{L(\beta)}{L(0)} \tag{3}$$

Where

ρ^2 = Rho-Square
$L(\beta)$ = Maximum Log Likelihood Function
$L(0)$ = Log Likelihood Function when all parameters equal 0

2) Comparison among the developed models that have a different number of independent variables with LL ratio-test Method (Hensheret al., 2005). Its equation is displayed as Equation 4.

$$2(LL_{\text{base model}} - LL_{\text{estimates model}}) \sim \chi^2_{(\text{number of new parameters estimated in estimated model})} \tag{4}$$

Where
$LL_{\text{base model}}$ = Likelihood Function of base model

$LL_{estimates\ model}$ = Likelihood Function of estimates model
$\chi^2_{(number\ of\ new\ parameters\ estimated\ in\ estimated\ model)}$ = Chi-Square of difference of independent variables between 2 models

3. RESULTS AND DISCUSSIONS

3.1 Socioeconomic Characteristics

The summary of characteristics of surveyed samples, including socioeconomic, residential location and trip purpose, are displayed in Table 6. It is noticed that average income of passenger car users (20,200 Baht/month) is much higher than that of motorcycle users (8,400 Baht/month). In addition, more than a half of motorcycle users are students.

Table 6. Socioeconomic characteristics of samples

Socioeconomic Characteristic		Passenger Car Users	Motorcycle Users
Sex	Male	59%	47%
	Female	41%	53%
Age	Average (year)	34	26
Income	Average (Baht/month)	20,200	8,400
Driving License	Yes	89%	79%
	No	11%	21%
Residential Location	≤ 400 m	33%	38%
	> 400 m	67%	62%
Occupation	Student	18%	57%
	Private Business Owner	21%	9%
	Officer	23%	16%
	Governmental Officer	30%	7%
	Etc.	8%	11%
Trip Purpose	Study	5%	11%
	Work/Business	65%	34%
	Etc.	30%	55%

3.2 Results of Model Development and Selection

Selection of Binary Logit models between private vehicles (MC and PC) and different systems of BRT was performed. The summarized results of model development are presented in Table 7. It reveals that the developed models provide high values of Likelihood Ratio Index (ρ^2) and Percent Correctly Estimated (% Correct).

Table 7. Binary Logit models

Type of Public Transit		Motorcycle Users (MC)		Passenger Car Users (PC)
Minibus (MNB)	M1	U_{MNB} = 3.62 -0.20TTMNB -0.22CMNB U_{MC} = -0.33TTMC -0.10CMC (ρ^2 = 0.391, % Correct = 80.00%)	M4	U_{MNB} = 3.47 -0.26TTMNB -0.16CMNB U_{PC} = -0.30CPC (ρ^2 = 0.497, % Correct = 86.67%)
BRT w/o P&R and Feeder (BRT)	M2	U_{BRT} = 4.27 -0.26TTBRT -0.22CBRT +1.28AGE U_{MC} = -0.25TTMC -0.18CMC (ρ^2 = 0.380, % Correct = 75.00%)	M5	U_{BRT} = 9.41 -0.39TTBRT -0.23CBRT U_{PC} = -0.35CPC +3.00LICENSE (ρ^2 = 0.469, % Correct = 85.00%)
BRT with P&R and Feeder (BRTS)	M3	U_{BRTS} = 2.01 -0.28TTBRTS -0.23CBRTS +0.74SEX +1.47AGE U_{MC} = -0.69CMC (ρ^2 = 0.403, % Correct = 80.00%)	M6	U_{BRTS} = 6.20 -0.28TTBRTS -0.15CBRTS +0.62SEX -0.89AREA U_{PC} = -0.19CPC +1.22LICENSE (ρ^2 = 0.251, % Correct = 78.33%)

3.3 Discussion of Developed Models

The developed models can be further discussed as follows:

3.3.1 Variables influencing mode choice

1) The signs of coefficients of travel time and travel cost of all systems of BRT (TTMNB, TTBRT, TTBRTS, CMNB, CBRT, and CBRTS) and both types of private vehicles (TTMC, CMC, and CPC) are minus as expected. The preference of travelers would be decreased while the travel time and cost increases.
2) The signs of coefficients of motorcycle user's age (+1.28 in M2 and +1.47 in M3) have a plus sign in case of more highly efficient system (BRT and BRTS). This means that older motorcycle users prefer to travel by more highly efficient system than younger motorcycle users.
3) The signs of coefficients of private car user's gender (+0.74 in M3 and +0.62 in M6) have a plus sign in case of the most highly efficient system (BRTS). This means that female private car users prefer to travel by more highly efficient system than male private car users.
4) The signs of coefficient of passenger car user's driving license holding (+3.00 in M5 and +1.22 in M6) have a plus sign in case of more highly efficient system (BRT and BRTS). This means that the passenger car users without driving license holding prefer to travel by more highly efficient system than the passenger car users with driving license holding.
5) The sign of coefficient of passenger car user's residential location (-0.89 in M6) has a minus sign in case of the most highly efficient system (BRTS). This means that the passenger car users whose residential location is within 400 m. from the station prefer to travel by the most highly efficient system than the passenger car users whose residential location is further than 400 m. Although the most highly efficient system (BRTS) provides the P&R at end-of-line stations, it is less accessible for the passenger car users who live in the city and further than 400m. from the station.

3.3.2 Proportion of bus rapid transit choice

The proportions of bus rapid transit choice by private vehicle users are presented by various systems in Figure 3. It reveals that more highly efficient system attracts more private vehicle users. The percentages of BRTS choice by private car users are significantly higher than MNB choice (+39% shift of MC users and +29% shift of PC users). All BRT systems attract the motorcycle users to shift to BRT more than the passenger car users. In case of the most highly efficient system (BRTS), more than half of motorcycle users shift to travel by BRT; in contrast, more than half of passenger car users still want to travel by their existing mode. The most highly system (BRTS) provides the P&R for motorcycle users at every station. It increases more accessibility for motorcycle users to use BRT. Nevertheless, the main part of passenger car users remains to use their existing mode since it provides more convenience and less travel time than BRT.

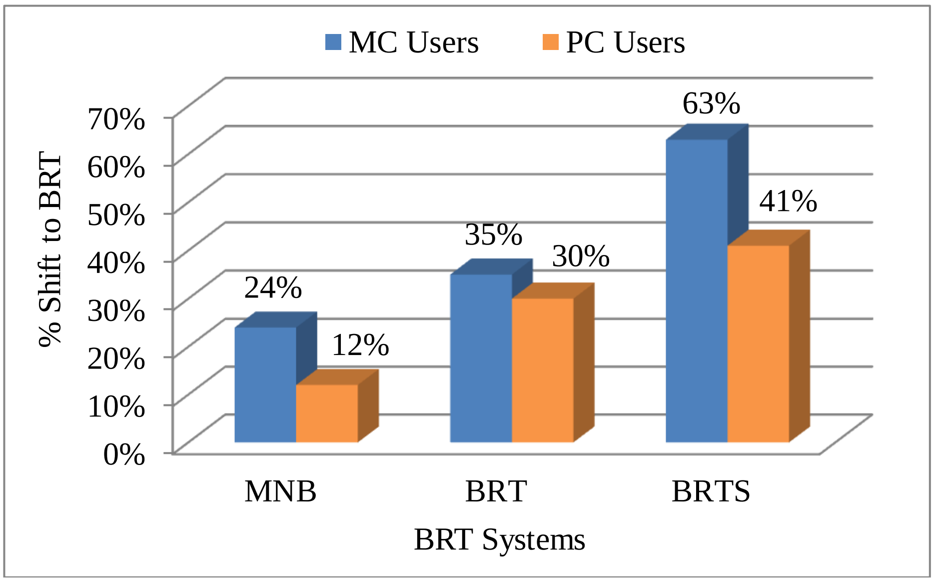


Figure 3. Percentage of private vehicle users shifting to BRT systems

3.3.3 Value of time

The values of BRT travel time of private vehicle users are displayed by various systems in Figure 4. It can be seen that all time values of all BRT systems of passenger car users (1.62 Baht/min. for MNB, 1.70 Baht/min. for BRT, and 1.86 Baht/min. for BRTS) are higher than those of motorcycle users (0.91 Baht/min. for MNB, 1.18 Baht/min. for BRT, and 1.23 Baht/min. for BRTS, respectively). This reflects that the average income of passenger car users is higher than that of motorcycle users. Car users are willing to pay more for time saving. Furthermore, the highly efficient systems give the higher values of time for both private car user groups; they are willing to pay more for highly efficient system even to save the same amount of travel time. The values of BRT travel time of the motorcycle users (0.91 Baht/min. for MNB, 1.18 Baht/min. for BRT, and 1.23 Baht/min. for BRTS) were compared with the value of shuttle bus travel time of Khon Kaen University (KKU) students traveling by motorcycle, which is 0.64 Baht/min (Satiennam et al., 2011). There are several reasons for this: the value of time is increased over time, the proposed BRT systems for Khon Kaen City are more efficient than the proposed shuttle bus in KKU, and the sampling group of this study includes not only the students but also the workers who are able to pay more to save the travel time.

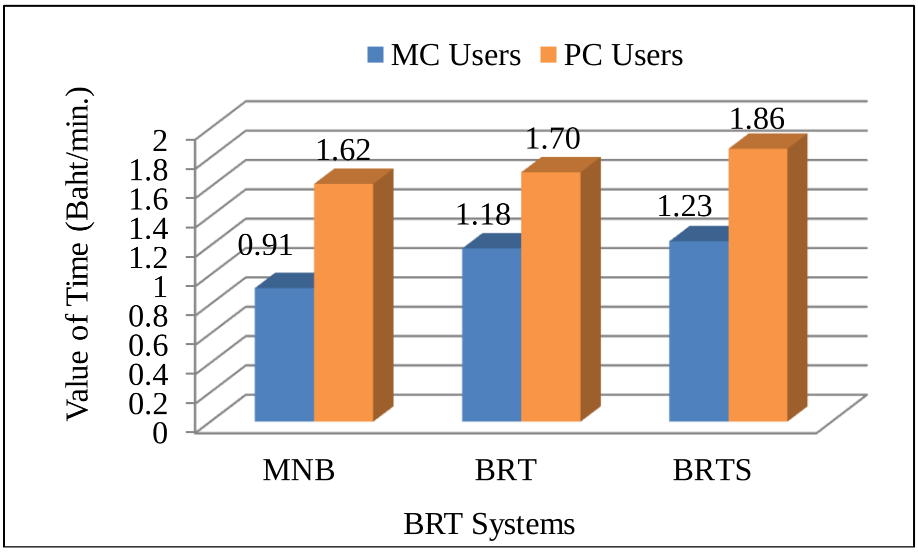


Figure 4. Value of time of private vehicle users in Khon Kaen City

3.3.4 Elasticity analysis

The elasticity analysis is a unit-less indicator that describes the percentage of change in variables influencing the percentage of change in mode choice (Louviere et al., 2000). The direct and cross elasticities resulted from the developed models are displayed in Table 8.

Table 8. Results of elasticity analysis

Travel Time	Direct Elasticities		Cross Elasticities	
	MC user	PC user	MC user	PC user
MNB Trip	-2.68	-3.37	0.85	0.46
BRT Trip	-2.12	-2.87	1.14	1.25
BRTS Trip	-0.92	-2.69	1.59	1.85
Travel Cost	**Direct Elasticities**		**Cross Elasticities**	
	MC user	PC user	MC user	PC user
MNB Trip	-2.28	-1.13	0.72	0.16
BRT Trip	-1.13	-1.04	0.61	0.45
BRTS Trip	-0.50	-0.55	0.85	0.38

As a result of direct elasticity analysis, both groups of private vehicle users are sensitive to the travel time and the travel cost of most systems of BRT (MNB, BRT, and BRTS) (Elasticities > 1), except the travel cost of the most highly efficient system (BRTS). However, they are more sensitive to the travel time of all systems of BRT (MNB, BRT, and BRTS) than the travel cost. Moreover, they are less sensitive to both travel time and the travel cost of BRT in case of more highly efficient system. Furthermore, the passenger car users are more sensitive to the travel time of all systems of BRT (MNB, BRT, and BRTS) than the motorcycle users (MNB: |-3.37|(PC) > |-2.68|(MC), BRT: |-2.87|(PC) > |2.12|(MC), BRTS: |-2.69|(PC) > |-0.92|(MC)); vice versa, the motorcycle users are more sensitive to travel cost than the passenger car users in case of lower efficient systems (MNB and BRT) (MNB: |-2.28|(MC) > |-1.13|(PC), BRT: |-1.13|(MC) > |-1.04|(PC)). It means that decreasing travel time of the BRT considerably influences increasing number of passenger car users, making more shifting to travel by BRT compared to motorcycle users. Besides, decreasing travel cost of the BRT has impact on the number of motorcycle users, who shift to travel by BRT more than passenger car users.

As a result of cross elasticity analysis, both groups of private vehicle users are not sensitive to bus's fare, but are sensitive to travel time of more highly efficient systems (BRT and BRTS). Nevertheless, the passenger car users are more sensitive to travel time of BRT than the motorcycle users (BRT: |1.25|(PC) > |1.14|(MC), BRTS: |1.85|(PC) > |1.59|(MC)). It means that increasing of travel time of BRT sensitively influences increasing number of private vehicle users, returning to use their existing modes, especially, the passenger car users.

4. APPLICATION OF DEVELOPED MODEL FOR BRT PLANNING

This study proposes the developed models choices between the most highly efficient BRT (BRTS) and private vehicles (MC and PC) since the BRTS make the highest proportion of private vehicle users shifting to BRT. The developed models were applied to evaluate the proposed policies to support the BRT project in Khon Kaen City in order to encourage more private vehicle users switching to travel by BRT. The proposed policies are as follows.

4.1 Decreasing Travel Time of Bus Rapid Transit

Service improvement can be done by decreasing travel time of BRT. This is tested by reducing 5%, 10%, 15%, and 20% of the current total travel time. The results are displayed in Figure 5. We found that once total travel time is decreased, the percentage of BRT choice by both private vehicle users increases. When travel time decreases by 20% of average observed total travel time, the number of passenger users switching to use BRT (from 41% to 63%, +22%) became higher than motorcycle users (from 61% to 72%, +11%). This proposed policy can be implemented through a strategy of increasing service frequency.

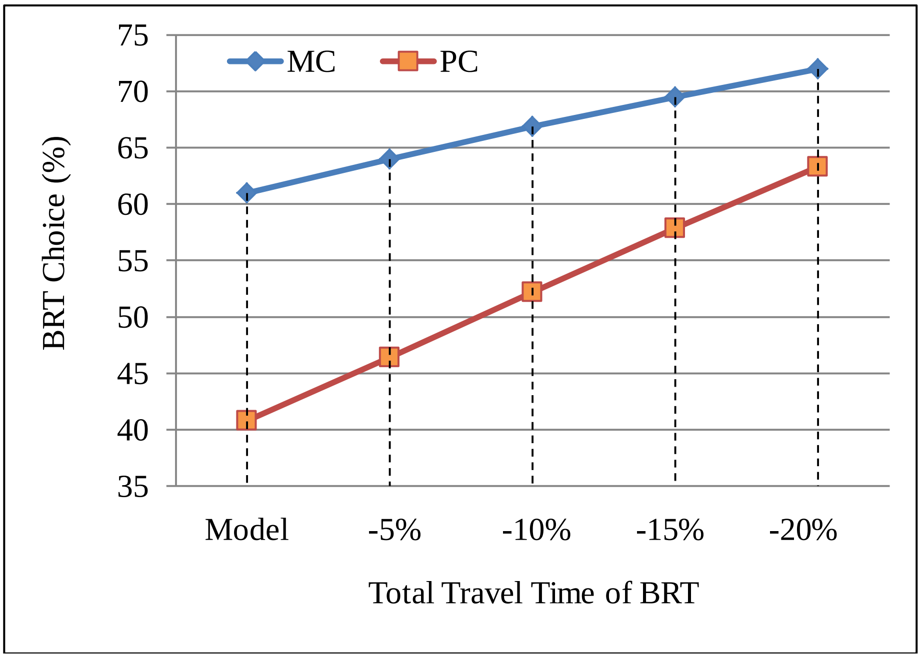


Figure 5. Percentage of BRT use with decreasing total travel time

4.2 Changing Fare of Bus Rapid Transit

Service improvement can also be done by reducing BRT fare. This is tested by setting fare at 0, 5, 10 (a current fare or a fare of the model) and 15 Baht. The results are displayed in Figure

6. It was found that if the fare decreases at half of current fare (from 10 Baht to 5 Baht), it results in increasing number of motorcycle users switching to use BRT (from 63% to 77%, +14%), a little higher than passenger car users (from 40% to 53%, +13%).

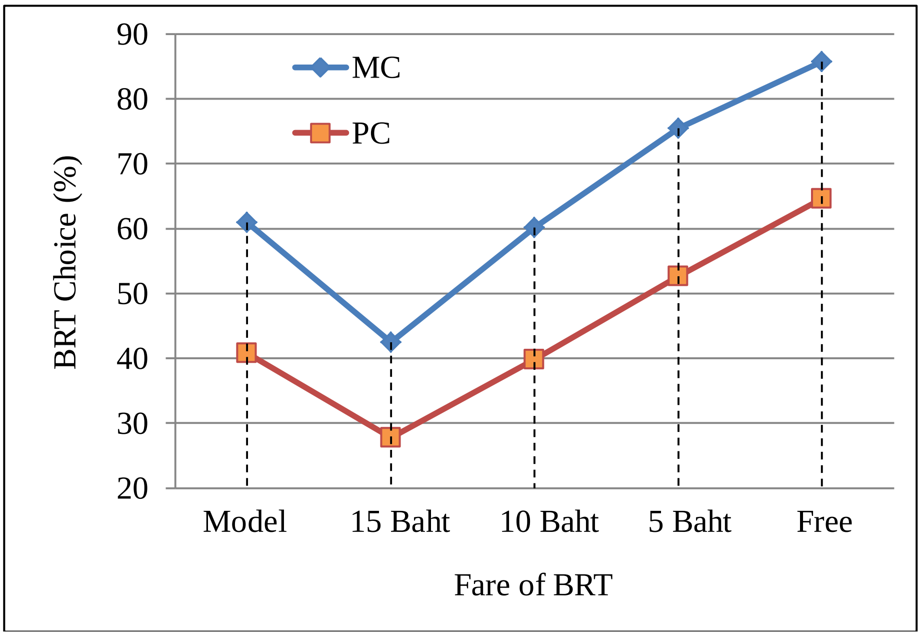


Figure 6. Percentage of BRT use with decreasing fare

4.3 Increasing Travel Cost of Private Vehicles

Decreasing the utility of using private vehicles (MC and PC) can also be done by increasing travel cost of private vehicle users. If the private vehicle users have to pay more by 2, 4, 6, and 8 Baht, the results are presented in Figure 7. We found that when travel cost of private cars is increased by 8 Baht (increasing 100% and 44% of average observed travel cost of MC and PC, respectively), it results in increasing number of motorcycle users switching to use BRT (from 63% to 94%, +31%). This is higher than passenger car users (from 41% to 64%, +23%). This proposed policy can be implemented through a strategy of charging the parking fee.

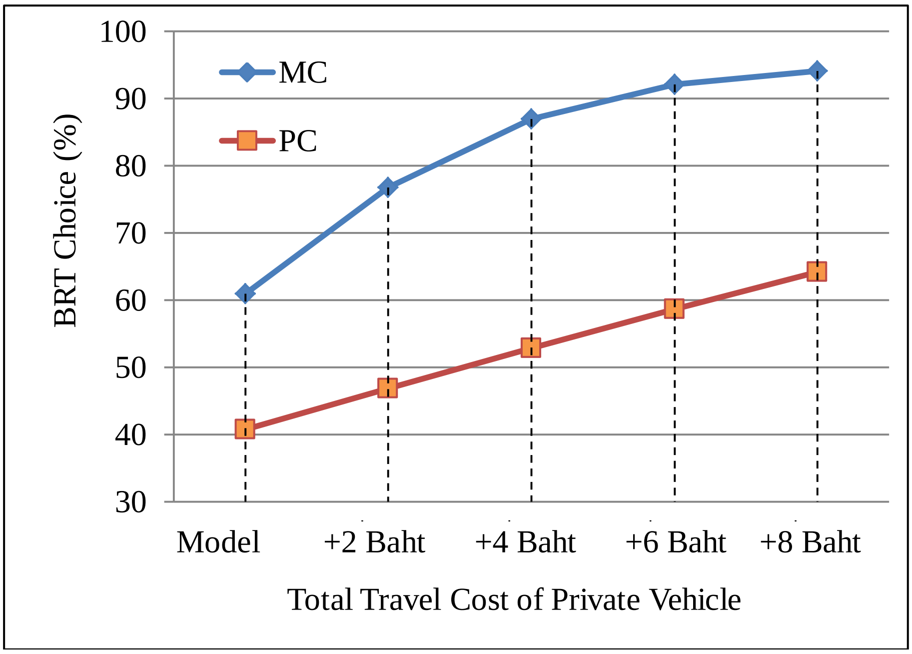


Figure 7. Percentage of BRT use with increasing total travel cost of private vehicles

5. CONCLUSIONS AND RECOMMENDATIONS

The choices of BRT systems with proposing policies, found in this study, are summarized in Table 9. It summarizes that more highly efficient system attracts more private vehicle users. All BRT systems attract the motorcycle users to shift to BRT more than the passenger car users. In case of the most highly efficient system (BRTS), more than half of passenger car users still want to travel by their existing mode, however more than half of motorcyclists shift to travel by BRT. Implementing most highly efficient system (BRTS) with various policies of decreasing total travel time and fare of BRT, as well as increasing total travel cost of private vehicles can increase BRT choice of both groups of private car users.

Table 9. Summary of BRT Choice

BRT Systems and Policies	BRT Choice (%)	
	PC Users	MC Users
Minibus (MNB)	12%	24%
BRT without P&R and Feeder (BRT)	30%	35%
BRT with P&R and Feeder (BRTS)	41%	62%
- with policy of decreasing 20% of total travel time of BRT (by, e.g., increasing service frequency)	63% (+22%)	73% (+11%)
- with policy of decreasing 50% of fare	53% (+12%)	77% (+15%)
- with policy of increasing 100% and 44% of total travel cost of MC and PC, respectively (by, e.g., charging parking fee)	64% (+23%)	94% (+32%)

The conclusions and recommendations of this study are listed below.

1) Travel time and travel cost of BRT influence choice decision of both groups of motorcycle and passenger car users.

2) The socio-economic characteristics of private vehicle users, including gender, age, driving license holding, and residential location, influence BRT choice.
3) Travel time has highly significant effect on car users' choice of BRT; in which travel cost has highly significant effect on motorcyclists.
4) The BRT system with P&R and free feeder system achieves considerably result in more private car users shifting to BRT, much higher than if the system mainly improves only vehicle (approximately, +40% shifts of MC users and +30% shifts of PC users).
5) The BRT system with P&R and free feeder system could attract more than half of motorcyclists.
6) Even the high efficient BRT system is provided, it is difficult to shift the passenger car users to BRT, and thus travel demand management should be integrated to "attract" car users to BRT.

These findings would be useful for BRT planning in Asian developing cities which encounter high percentage of private vehicle share, especially motorcycle usage. BRT system has high potentials in attracting private vehicle users. The main concerns in planning BRT is that the system should provide significant decrease of travel time, reasonable fare level for low and medium income groups (subsidy may be needed), well designed P&R stations, and free feeder systems.

ACKNOWLEDGEMENTS

The data of this study is supported by the Sustainable Infrastructure Research Development Center (SIRDC), Department of Civil Engineering, Faculty of Engineering, Khon Kaen University, Thailand.

REFERENCES

Arasan, V.T. and Vedagiri, P. (2011) Modelling Modal Shift from Personal Vehicles to Bus on Introduction of Bus Priority Measure, *Asian Transport Studies*, 1(3), 288-302.

Barr, J., Beveridge, J., Clayton, C., Danaher, A., Gonsalves, J., Koziol, B. and Rathwell, S. (2010) *Designing Bus Rapid Transit Running Ways.* American Public Transportation Association.

Ben-Akiva, M. and Lerman, S.R. (1985) *Discrete Choice Analysis: Theory and Application to Travel Demand*. MIT Press, Cambridge.

Ernst, J.P. (2006) Initiating Bus Rapid Transit in Jakarta, Indonesia. *Journal of the Transportation Research Board*, 1903, 20-26.

Jaensirisak, S. (2005) Stated Preference Techniques and Its Applications. *Proceeding of the 10th National Civil Engineering Conference Chonburi*, 2-4 May 2005.

Jaensirisak, S. and Klungboonkrong, P. (2009) Why Bus Rapid Transit (BRT) is Interested by Transport Planners and Travellers in Thailand, *Proceedings of the Eastern Asia Society for Transportation Studies*, 7.

JICA, MOT, and HCMC-PC. (2004) *The Study on Urban Transport Master Plan and Feasibility Study in Ho Chi Minh Metropolitan Area – HOUTRANS.* Japan International Cooperation Agency (JICA), Ministry of Transport, Socialist Republic of Vietnam (MOT) and Ho Chi Minh City People's Committee (HCMC-PC), Hanoi (www.houtrans.org).

Limanond, T., Butsingkorn, T. and Chermkhunthod, C. (2010) Travel behavior of university students who live on campus: A case study of a rural university in Asia, *Transport Policy*.

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000) *Stated Choice Methods: Analysis and Application*. UK: Cambidge University Press.

Richards, M.G. and Ben-Akiva, M.E. (1975) *A Disaggregate Travel Demand Model*. D.C. Heath Ltd., England.

Satiennam, T, Fukuda, A, and Oshima, R, (2006) A Study on the Introduction of Bus Rapid Transit System in Asian Developing Cities - A Case Study on Bangkok Metropolitan Administration Project –, *IATSS Research*, 30(2), 59-69.

Satiennam, T, Fukuda, A, and Oshima, R, (2007a), Strategies Enhancing Bus Rapid Transit Development in Asean Developing Cities - A Case Study on Bangkok Metropolitan Administration Project -, *the 86th Annual Meeting of the Transportation Research Board*, Washington, D.C.

Satiennam, T, Fukuda, A and Kaneko, Y, (2007b), Demand Supply Policy for Bus Rapid Transit Development in Asian Developing Cites - Accumulating Demands from Urban Sprawls to BRT Corridor by Paratransit Feeder -, *11th World Conference on Transport Research*, Berkeley, USA.

Satiennam, T., Jaensirisak, S., Natevongin, N. and Kowtanapanich, W. (2011) Public Transport Planning for a Motorcycle Dominated Community, *Journal of the Eastern Asia Society for Transportation Studies*, 9, 970-985.

Schipper, L., Huizenga, C., and Ng, W. (2005) Indicators: Reliable signposts on the road to sustainable transportation – The partnership for sustainable transport in Asia. *The eceee 2005 Summer Study Proceedings*, Mandelieu, France.

SIRDC (2008) *A Master Plan of Khon Kaen Transit System*, A Final Report, Khon Kaen Municipality and Sustainable Infrastructure Research and Development Center, Khon Kaen University.