ANALYSIS OF ACCESS MODES IN SUBURBAN COMMUNITIES USING SEM APPROACH

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Abstract: The structural equations analysis can be used to reveal and examine the decision making process on mode. The structural equation model can extract personal attitude and perception and handle the measurement errors often associated with travel time and travel cost. Travelers in the study area need certain services for connecting them to the main network. To decrease their total travel times, such services need to approach the characteristics of private transport rather than those of fixed routes and fixed scheduled services. Accordingly, motorcycle-taxi is very popular in this area and plays the most significant role as a short haul transport mode shuttling people from their houses to the transit stops due to its less time-consuming, mobility, and demand-responsive ability. The proposed policy in this study is the introduction of shuttle bus transferring people to the railway station. The pilot project was adopted and the results showed that it was warmly welcomed.

Key Words: Access mode, Motorcycle-Taxi, Shuttle bus, Structural equation model, SEM

1. INTRODUCTION

In Bangkok, rapid population growth has meant that housing has developed in suburban areas inadequately served by public transport services. This can have an effect on the quality of life of residents of these areas in term of access to employment, school, shopping, and medical facilities. This serious problem is occurred not only for isolated communities but also inner residential areas. Even though the inner communities are provided with more alternatives of public services, some of them are used only by the nearby commuters due to lacking of proper and sufficient access modes to these transit systems.

According to the difficulty of using public services, travelers in these areas are more likely to use private vehicles in order to avoid stresses caused by this inconvenience which will lead to not only economic problem, but also environmental and quality of life aspects. To avoid these problems which are now become more serious, some policies of transit incentive should be applied. This study focuses on (1) generating a travel behavioral model for travelers in suburban communities, (2) studying the characteristics and behaviors of both travelers and available access modes, (3) introducing some policies to attract choice riders to shift their transport modes from private vehicles to transit services and to enhance the quality of traveling for captive riders, and (4) analyzing the sensitivity of the proposed policies. The inefficiency of accessibility to transit systems provided in suburban areas of Bangkok is the main idea of this study. Even though there are adequate alternative choices of transit services served in these areas, there are some trade-offs who cannot easily use some of them as their own wishes although their houses are located not too far away from those transit terminals due to the poor level of access mode services.

To illustrate this problem, the Muang Thong Thani community, located in Pakkred district of Nonthaburi province lying next to the northern borderline of Bangkok, is selected to be a representative of the suburban area community. In this community and the nearby area, there are totally four transit services; which are Rail, Taxi, Public van, and Bus, provided for commuters. It seems to be very convenient to them, but in fact, a small number of travelers use rail even though its station is located only about five kilometers far away from their houses. The questions are “Why do they ignore traveling by rail?” as well as “What are the characteristics and behaviors of the available access modes?”, and “What are the suitable policies to enhance the level of transit services?”. In order to answer these questions, the general revealed preference (RP) data; such as socio-demographic of travelers, the

characteristics and behaviors of both travelers and services, and trip characteristics, should be observed prior to generating a travel behavioral model of commuters in this study area. Then, the stated preference (SP) data concerning with the introduction of a new mode for enhancing the quality of trip under hypothetical situations would be combined together with the observed RP data to evaluate the feasibility of the proposed policy for transit incentive. Even though SP data have inherent biases stemming, among other things, from the respondents' lack of familiarity with the new mode, a combination of RP and SP data is used in model estimation to overcome these potential biases and to provide more reliable estimates (Ben-Akiva and Morikawa, 1990a and 1990b; Hensher and Bradley, 1993; Ben- Akiva et al., 1994; Ben-Akiva and Morikawa, 1997; Bradley and Daly, 1997; Kuniaku et al., 1999).

This study mainly focuses on travel behaviors and characteristics of commuters in a suburban community. The transport modes that will be considered in this study are *Private vehicles*, *Taxi*, *Transit services*; which are Rail, Public van, and bus, and *Access modes*; which are walk, bicycle, local bus (or Song Taew), and motorcycle-taxi. A Structural Equation Modeling (SEM) approach is used to generate and calibrate the model. A policy of transit incentive concepts, *shuttle bus*, will be introduced for two main reasons; that are (1) to attract the choice riders to shift their mode choices from private vehicles to transit services, and (2) to enhance the quality of traveling for captive riders. The elasticity of the calibrated models, the sensitivity of the policies, and the before-and-after study will be analyzed in order that the most suitable policy will be recommended.

2. METHODOLOGY

2.1 Conceptual Framework

The overview of this study is explained by means of conceptual framework which is separated into four main groups of tasks consisting of Data Collection, Model Calibration, Behavioral Study, and Application.

The concepts are (1) to select the study area where is most suitable to collect the required data such as demographics of travelers, available mode of transport, and travel pattern; this stage is developed to identify the general information and characteristics of the study area, (2) to develop the questionnaire survey for both demand and supply sides in order to collect data by applying the random sampling strategy; Prior to distribution to respondents, the questionnaire has to be clear and able to respond all required attributes which will be employed to develop the model, (3) to calibrate the model using structural equation modeling (SEM) approach; the *AMOS 4.0* software package will be employed to calibrate utility functions, generate a model, and test its validity, (4) to study the behaviors and characteristics of both travelers and transport modes from the observed data by defining them into categories, illustrating the verified data, and giving their descriptions, (5) to analyze the elasticity of each attribute prior to developing the policy of transit services incentive; this stage is developed to find out the significant parameters or attributes that most affect to the travel behavioral model, (6) to propose some policies of transit incentive according to the hypothetical situations (SP) and the results from the stage of elasticity analysis, and (7) to analyze the sensitivity of the proposed policies in order that the results can be applied to recommend the most suitable policy which will further be implemented.

2.2 Study Area

The study area, Muang Thong Thani community, is located on Chaeng Wattana road, in Pakkred district of Nonthaburi province lying next to the northern border line of Bangkok. The total area is more than 4,000 rai or approximated 1,600 acres in piece of land with the approximated 80,000 population. This accommodation type is now become popular among the middle through high income people due to the provision of the necessary facilities such as school, bus depot, sport club, market, department store, and convention hall, which can make commuters' life more convenient and comfortable.

There are four different transit services provided in this community and the nearby areas which are Rail, Taxi, Public van, and Bus service. The location of transit service stations are shown in figure 1. The distance from the study area to Laksi railway station is about four kilometers. For bus service, there are totally three bus stops in this area. One bus depot with a

few number of bus routes is provided in the Muang Thong Thani community where the other two bus stops are located at the entrance and exit ways on both Tivanont and Chaeng Wattana roads with the approximated same distance of 1.0 kilometer from the center point. A public van depot is located inside the community providing a great variety of destination choice with more than 15 different routes including expressway and non-expressway services. Furthermore, there are totally four access modes available in this area for linking passengers to the transit services which are Walking, Bicycling, Song Taew (or Local bus), and Motorcycle-Taxi. The structure of commuters' traveling pattern is illustrated in figure 2.

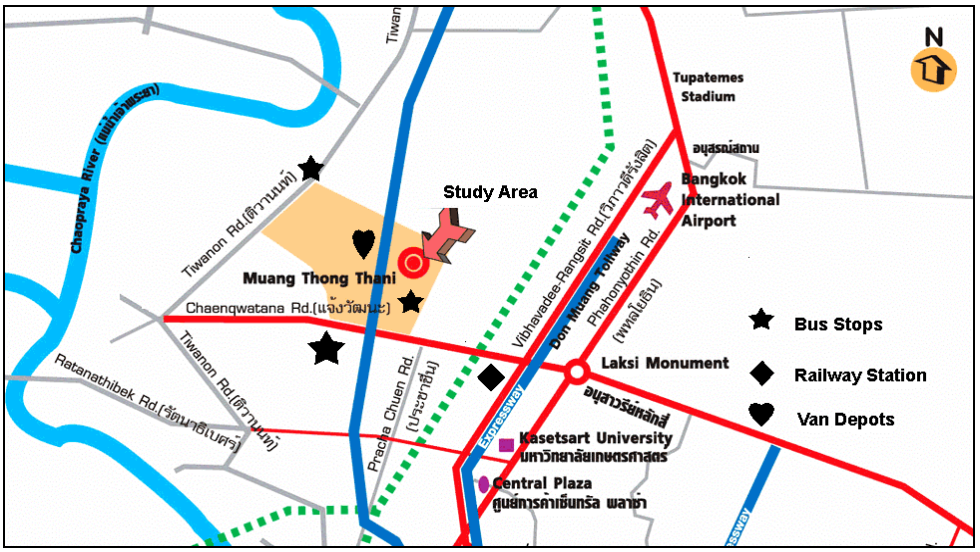

Figure 1. Locations of the Study Area and Transit Stops

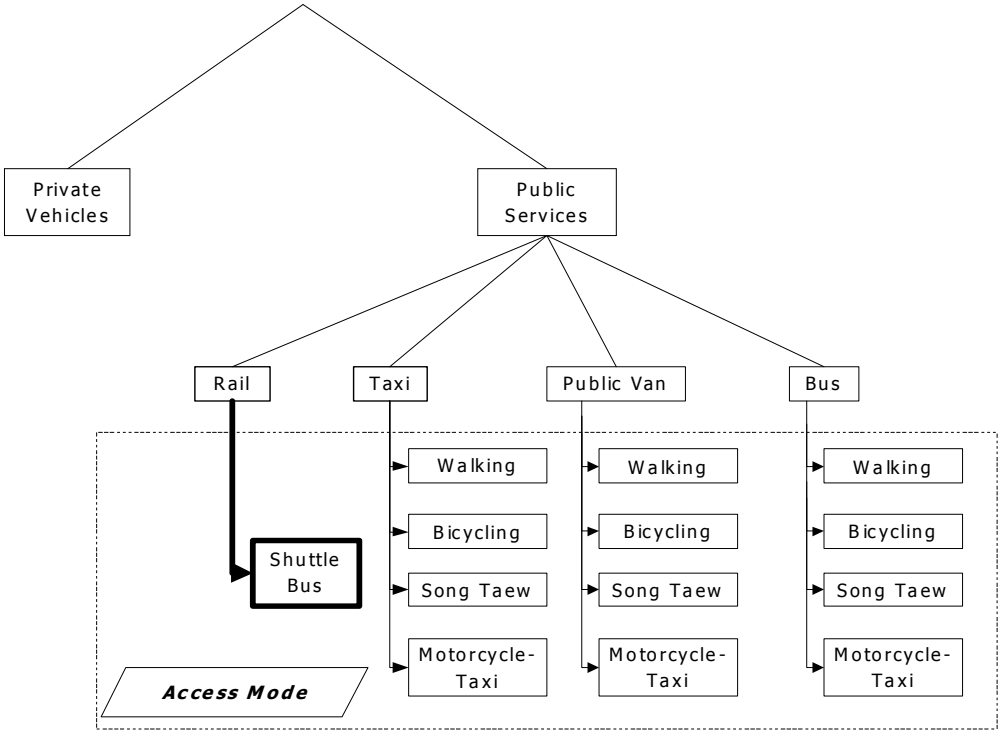

Figure 2. Traveling Structure of Commuters in the Study Area

2.3 Model

It is assumed in this study that mode choice utility is a function of modal characteristics, trip characteristics, travelers' demographic, and the attitude perceptions. The hypothesized model to be tested, therefore, consists of four primary factors, Mode Char, Demographic, Trip Char, and Attitude, and one secondary factor, Mode Utility, as shown in figure 3, where its component parts are listed as follows:

1. There are five factors, as indicated by the five ellipses labeled Mode Char, Demographic, Trip Char, Attitude, and Mode Utility.
2. The four factors are intercorrelated, as indicated by the two-headed arrows.
3. There are 27 observed variables, as indicated by the 27 rectangles; they represent item pairs from the mentioned factors subscales of the Demand Survey Questionnaire.
4. ach observed variable loads on one and only one factor.
5. Errors of measurement associated with each observed variable are uncorrelated.

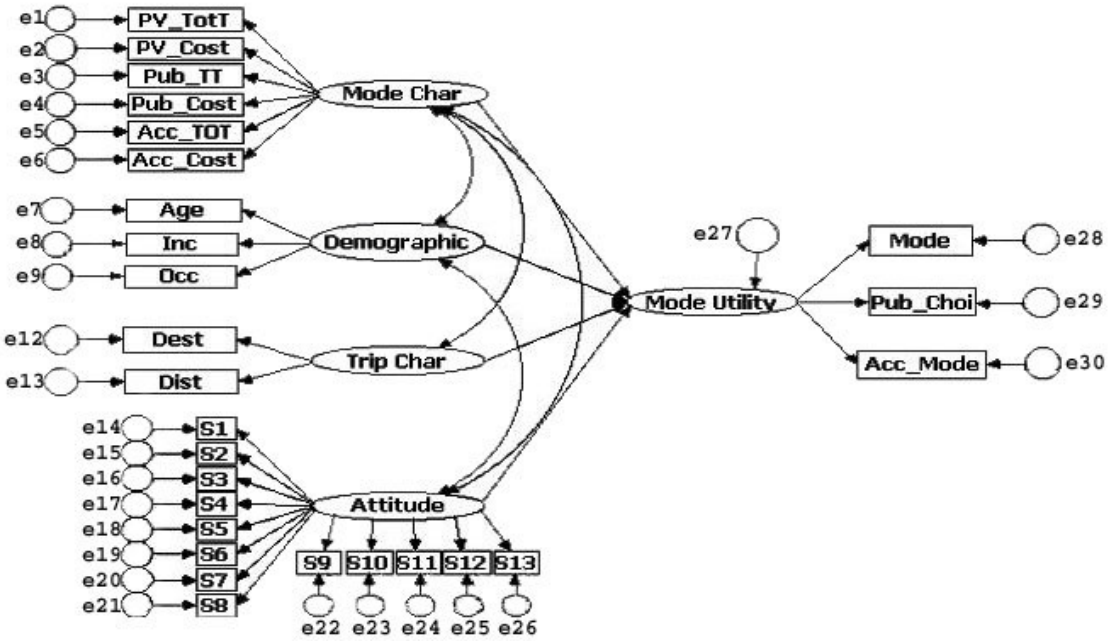

Figure 3. the First Hypothesized five-factor model of Mode Utility

The general conceptual model of commuter's choice is presented in figure 4, where the rectangles indicate the observable or manifest variables, and the ellipses indicates the unobservable or latent variables. Furthermore, as shown in figure 5, it is hypothesized in this study that the access mode choice is affected by the public mode choice meaning that the individual decides on his/her public mode choice first and then on his/her access mode choice.

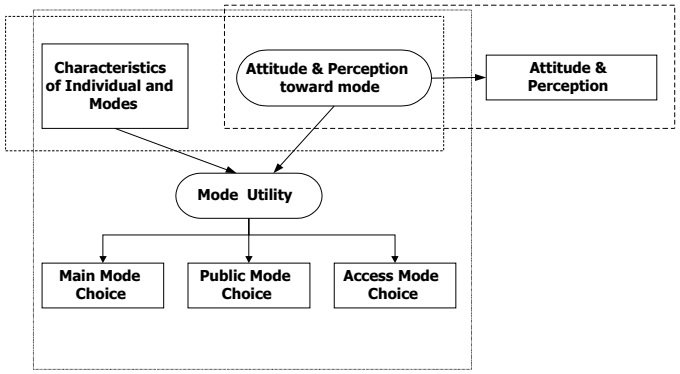

Figure 4. The General Conceptual Model of Commuter's Choice

As stated by R. Sakano and J. Benjamin in 2001, the model proposed in this study has many methodological advantages over nested multinomial logit models. First, the model uses path analysis to specify causation among variables and to test a decision process of mode choice specified in the model. Second, the structural equation model can explicitly include latent variables such as individual attitude and perception toward mode and travel. Third, the model can assume a measurement error on observed variables and estimate unobserved actual values from them, which fit best to the observed mode choices.

The analysis procedure is based on a structural equation model using AMOS 4.0 computer software package, which has an advantage on its ability to run a model by graphical method. AMOS Graphic provides a graphical interface through which the user conducts an analysis by drawing the model on the screen. Once the analysis is executed, AMOS reports the progress of the estimation and then displays the output in a text file. AMOS Graphics also offers a feature called the Modeling Laboratory in which the user can select an individual parameter, change its value, and observe how this change affects the fit of the whole model.

In this study, there are two proposed models of which the functional forms among endogenous and exogenous variables are linear. As shown in figure 3, the first model is a general hypothesized model of mode utility which is used to describe the relationship among the endogenous and exogenous variables in order to set up the utility function and to calculate and predict the traveler's modal choice. The second model is a specific hypothesized model based on the hypothesis that the access mode choice is affected by the public mode choice, as shown its postulated structure in figure 5. The descriptions of the variables related to the models are shown in Table 1. This study will aim to test the second model in the present application derives from the surveying so the model hypothesized a priori that:

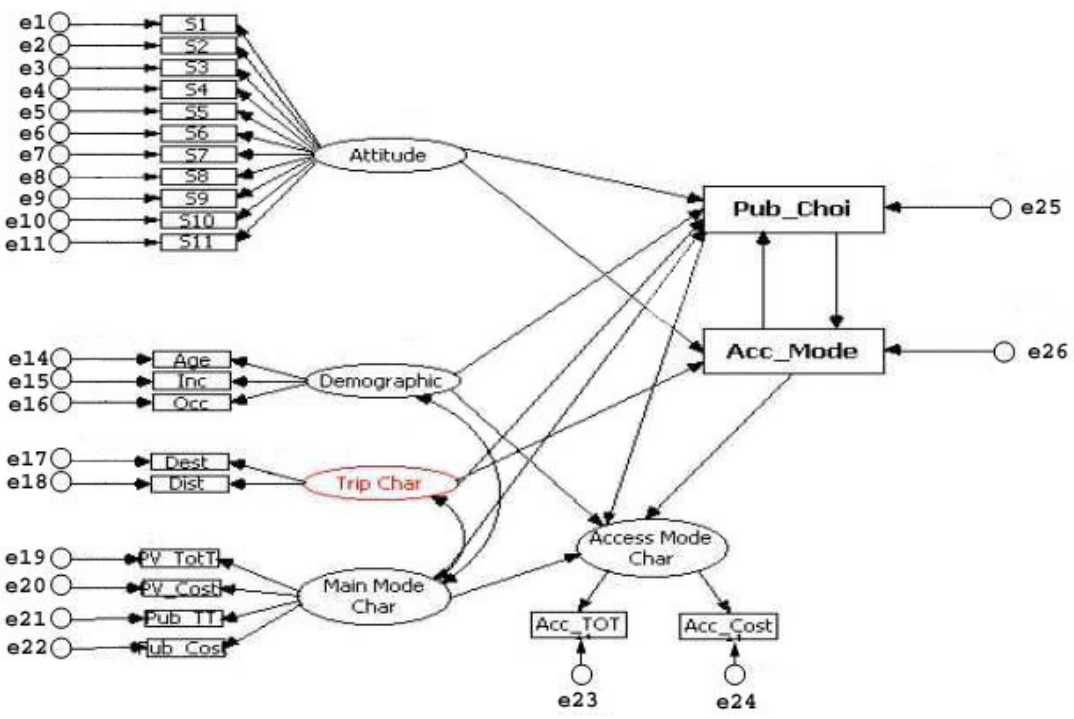

Figure 5 the Second Hypothesized Model of Commuter's Choice

1. Responses to the public mode choice could be explained by four first-order factors (Mode Char, Demographic, Trip Char, and Attitude) while responses to the access mode choice could be explained by two first-order factors (Trip Char and Attitude), and one second-order factor (Access Mode Char).
2. Each item would have a non-zero loading on the first-order factor it was designed to measure, and zero loadings on the other second-order factors.
3. Error terms associated with each item would be uncorrelated.

Table 1 Variables Description

VARIABLES		NAME	DESCRIPTION
Socio-Demographic Variables	Gender	Gender of respondent	1 = Male, 2 = Female
	Age	Age of respondent	Numeral
	Inc	Monthly household income	Numeral
	Occ	Occupation	1 = Student
			2 = Professional
			3 = Government officer
			4 = Business owner
			5 = Private company employee
			6 = Others
	Chld	Number of children	Numeral
	Edu	Education level of respondent	1 = lower than undergraduate
			2 = undergraduate or higher
	Vos	Vehicle ownership	Numeral
	Noe	Number of employees	Numeral
Trip Characteristics Variables	Obj	Trip purpose	1 = School trip
			2 = Work trip
			3 = Shopping trip
			4 = Others
	Dest	Trip destination (Zone)	1 - 16 Zonal number
	Dist	Trip distant	1 = less than 10 km.
			2 = 10 - 15 km.
			3 = 16 - 20 km.
			4 = more than 20 km.
Main Mode Characteristics Variables	PV_TT	Private total time	Numeral
	PV_TC	Private total cost	Numeral
	Pb_TT	Public total time	Numeral
	Pb_TC	Public total cost	Numeral
Access Mode Characteristics Variables	AC_TT	Access mode total time	Numeral
	AC_TC	Access mode total cost	Numeral
Attitude Variables S1 – S13	Time	Attitude toward time	1 = Unimportant at all
	Cost	Attitude toward cost	2 = Somewhat unimportant
	Com	Attitude toward comfort	3 = No opinion
	Con	Attitude toward convenience	4 = Somewhat important
	Flex	Attitude toward flexibility	5 = Extremely important
	Safe	Attitude toward safety	

4. Covariation among the first-order factors would be explained fully by their regression on the second-order factor.

5. There is an intercorrelation between public choice and access choice which would have a non-zero-loading on each other.

Like the seeming unrelated regression method, the model which allows correlation among error terms can extract a part of the missing effects and take into account biased responses, and in turn, will lead to more efficient estimates and better predictions (R. Sakano and J. Benjamin, 2001). However, Unlike the regression analysis which focuses on mean prediction of each observation by minimizing the sum of squared errors or minimizing a likelihood function of errors, the structural equation analysis focuses on predicting variance-covariance matrix of observed endogenous and exogenous variables of overall observations, so there is no distributional assumption on an error of individual observation, Therefore, the structural equation analysis does not require a logit or probit type model used in the regression analysis, but assumes a linear function form (Kelloway, 1998).

3. SURVEY RESULTS

Three questionnaire surveys were conducted in the study area, which were Demand Side Survey, Supply Side Survey, and Before-and-After Opinion Survey. For the demand survey, 10,000 questionnaires asking about personal characteristics, trip characteristics, commuters' attitude, mode choice, and the Important Rating Statements were randomly distributed to residents of the study area. The total amounts of 1,576 questionnaires were responded. However, among these, 208 questionnaires were deducted due to their potential errors in answering. Finally, the total amounts of effective respondents were 1,368 which were calculated to be 13.68%. The summary of questionnaire survey results from demand survey is presented in Table 2, 3, and 4. Mode Choice variables used on the estimation are a binary choice between private and public. Public mode choice variables are multiple choice among Taxi, Van, Bus, and Rail while access mode choice are also multiple choice among Walk, Bicycle, Song Taew (or Local Bus), and Motorcycle-Taxi.

To evaluate the success of proposed policy and the users' satisfaction, the before-and-after study was employed. The 250 before-study questionnaires were distributed to respondents asking about their demographics, opinion and attitude toward policy, and previous trip characteristics prior to provision of shuttle bus. After finishing the pilot project, the 250 afterstudy questionnaires were sent to the houses of the same respondents who answered to the before-study questionnaires. The results are presented in Table 15, 16, and 16, while the outcome of the statistical test is presented in the fifth section.

Table 2 Summary of Socio-Demographics

Individual Characteristics	Category or Range	Number of Respondents
Gender	Male	623 (45.54%)
	Female	745 (54.46%)
Age	< 30 years old	386 (28.22%)
	31 - 50 years old	664 (48.54%)
	> 50 years old	318 (23.24%)
Monthly Household Income	< 10,000 Baht	279 (20.39%)
	10,001 - 25,000 Ba	821 (60.02%)
	> 25,000 Baht	268 (19.59%)
Education Level	Lower than bachelo	565 (41.30%)
	Bachelor or higher	803 (58.70%)
Occupation	Student	167 (12.21%)
	Professional	290 (21.20%)
	Government Office	333 (24.34%)
	Business Owner	289 (21.13%)
	Private Employee	289 (21.13%)
Vehicle Ownership	None	593 (43.35%)
	1	611 (44.66%)
	2 or more	164 (11.99%)
Number of Employees	1	851 (62.21%)
	2 or more	517 (37.79%)
Number of Children	None	298 (21.78%)
	1	232 (16.96%)
	2	641 (46.86%)
	3 or more	197 (14.40%)

Table 3 Summary of Actual Mode Choice

Category	Transport Mode	Number of Riders
Main Mode Choice	Private	775 (56.65%)
	Public	593 (43.35%)
Public Mode Choice	Taxi	3 (0.51%)
	Van	287 (48.40%)
	Bus	266 (44.86%)
	Rail	37 (6.24%)
Access Mode Choice	Walk	19 (3.20%)
	Bicycle	25 (4.22%)
	Song Taew	229 (38.62%)
	Motorcycle-Taxi	320 (53.96%)

3.1.1 Facts Findings

- Private vehicle is more popular than public vehicle. [Private user shares 56.65% (775 out of 1368) while Public user shares 43.35% of all travelers (593 out of 1368).
- Female travelers are slightly more than male travelers (745:623).
- The numbers of higher educated travelers are greater than those of the lower educated travelers (803:565).
- Van is the most popular public main mode (48.40%), while bus is the first runner-up (44.86%).
- Motorcycle taxi is the most popular access mode (53.96%), while Song Taew (or local bus) is the first runner-up (38.62%).
- Most of trips generated in this area are work trips (87.79%).

Table 4 Summary of Individual Characteristics Variables

Individual char	Description	Min	Max	Mean		Std. Deviation	Variance
				Statistic	Std. Error		
GENDER	gender of respondents	1	2	1.54	0.01	0.50	0.25
AGE	age of respondents	17	62	39.36	0.32	12.01	144.22
INC	monthly household income	0	44700	17134.87	271.89	10056.42	101131607.01
CHLD	No. of children	0	3	1.54	0.03	0.99	0.97
EDU	education level	1	2	1.59	0.01	0.49	0.24
OCC	Occupation	1	5	3.18	0.04	1.31	1.73
VOS	vehicle ownership	0	2	0.69	0.02	0.67	0.46
NOE	No. of employees	1	2	1.38	0.01	0.49	0.24

Table 5 Summary of Trip Characteristics Variables

Trip char	Description	Min	Max	Mean		Std. Deviation	Variance
				Statistic	Std. Error		
OBJ	objective or trip purpose	1	2	1.88	0.01	0.33	0.11
DEST	trip destination	2	16	9.17	0.12	4.30	18.53
DIST	trip distant	1	4	2.90	0.02	0.88	0.78
MODE	main mode choice	1	2	1.43	0.01	0.50	0.25
ACC	access mode choice	0	4	1.49	0.05	1.77	3.13

Table 6 Summary of Private Mode Characteristics Variables

Private char	Description	Min	Max	Mean		Std. Deviation	Variance
				Statistic	Std. Error		
PV_IT	private in-vehicle travel time	25	120	67.23	0.82	22.87	523.04
PV_AT	private access time	5	10	7.47	0.06	1.66	2.75
PV_ET	private egress time	7	15	11.00	0.09	2.57	6.60
PV_TOTT	private total travel time	43	140	85.70	0.82	22.87	522.81
FUELCOST	monthly fuel cost	825	3960	2218.45	27.11	754.71	569594.11
EX_COST	monthly extra cost	0	2640	1254.14	35.33	983.44	967158.92
MMC	monthly maintenance cost	500	1400	948.65	10.45	290.90	84620.26
PV_COST	private total cost	1425	7395	4421.24	56.17	1563.60	2444858.02

Table 7 Summary of Public Mode Characteristics Variables

Public char	Description	Min	Max	Mean		Std. Deviation	Variance
				Statistic	Std. Error		
PUB_IT	public in-vehicle travel time	20	150	71.51	1.48	36.07	1301.05
PUB_AT	public access time	2	50	15.19	0.39	9.46	89.42
PUB_WT	public waiting time	5	30	15.30	0.29	6.95	48.37
PUB_ET	public egress time	3	40	14.15	0.23	5.61	31.47
PUB_TT	public total travel time	47	212	116.14	1.67	40.68	1654.67
PUB_COST	public total travel cost	220	5280	741.62	16.83	409.83	167959.54

Table 8 Summary of Access Mode Characteristics Variables

Access char	Description	Min	Max	Mean		Std. Deviation	Variance
				Statistic	Std. Error		
ACC_WT	access mode waiting time	0	15	5.19	0.19	4.54	20.64
ACC_TT	access mode travel time	5	35	13.87	0.25	6.09	37.08
ACC_TOT	access mode total travel time	5	38	19.06	0.35	8.43	71.08
ACC_COST	access mode total travel cost	0	20	9.05	0.22	5.24	27.43

Table 9 Summary of Important Rating Statement

Important Rating Statement	Scale			Average and Median
	Not Important (1 - 2)	No Opinion (3)	Important (4 - 5)	
S1: Ability to arrive on time	109 7.97%	191 13.96%	1068 78.07%	4.05 4
S2: Not having to deal with traffic congestion	94 6.87%	191 13.96%	1083 79.17%	4.08 4
S3: Short travel time	95 6.94%	88 6.43%	1185 86.62%	4.48 5
S4: Daily expenditure costs	730 53.36%	348 25.44%	290 21.20%	2.53 2
S5: Protection from weather	9 0.66%	562 41.08%	797 58.26%	3.76 4
S6: Having a seat	638 46.64%	374 27.34%	356 26.02%	2.7 3
S7: Short waiting time	168 12.28%	98 7.16%	1102 80.56%	4.03 4
S8: Ability to travel when desired	338 24.71%	252 18.42%	778 56.87%	3.82 5
S9: Ability to reach the exact destination	201 14.69%	250 18.27%	917 67.03%	3.72 4
S10: No need to transfer	390 28.51%	200 14.62%	778 56.87%	3.7 5
S11: Flexibility to change plans	390 28.51%	200 14.62%	778 56.87%	3.46 4
S12: Safety of vehicles	494 36.11%	496 36.26%	378 27.63%	2.84 3
S13: Freedom from threats to personal safety	462 33.77%	434 31.73%	472 34.50%	3.01 3

Table 10 Public Choice & Access Mode Choice Crosstabulation

		ACCESS MODE				Total
		Walk	Bicycle	Song	Motorcycle	
Public Choice	Taxi	0	0	3	0	3
	Van	7	16	97	**167**	**287**
	Bus	10	9	**112**	135	266
	Rail	0	0	18	19	37
Total		17	25	230	**321**	593

Table10 shows the relationship between public mode and access mode. Travelers who use van as their main mode and select motorcycle-taxi as their access mode share the biggest group among any possible pairs, which is reasonable due to the fact that van is the most popular

main mode and motorcycle-taxi is the most popular access mode. The second biggest group is the group of people who travel by bus and use Song Taew as their access mode. People traveling by rail normally use either Song Taew or motorcycle-taxi.

4. EMPIRICAL FINDINGS

4.1 Hypothesized Modeling with AMOS

The introduced model is based on the hypothesis that the travelers' access mode choices are affected by their public mode choices. The exploratory factor analysis was performed among each endogenous variable, which were Demographics, Attitude, Trip Char, Main Mode Char, and Access Mode Char. As shown in figure 3, thirteen "Important Rating Statement" were the exogenous variables used to identify the Attitude toward Time, Cost, Comfort, Convenience, Flexibility, and Safety. Age, Income, and Occupation variables were used to identify the Demographics. Total time and cost of Private and Public Mode were used to identify the Main Mode Char, while total time and cost of Access Mode were used to identify the Access Mode Char. These endogenous variables performed their relationship with two exogenous variables, which are public mode choice and access mode choice, as indicated in figure 6. According to the hypothesis, there is an intercorrelation between public mode and access mode choice, as indicated by two one-head arrows. Besides, each exogenous variable loaded on one and only one factor, and errors of measurement associated with each exogenous variable were uncorrelated. The model's results are shown in the following figures.

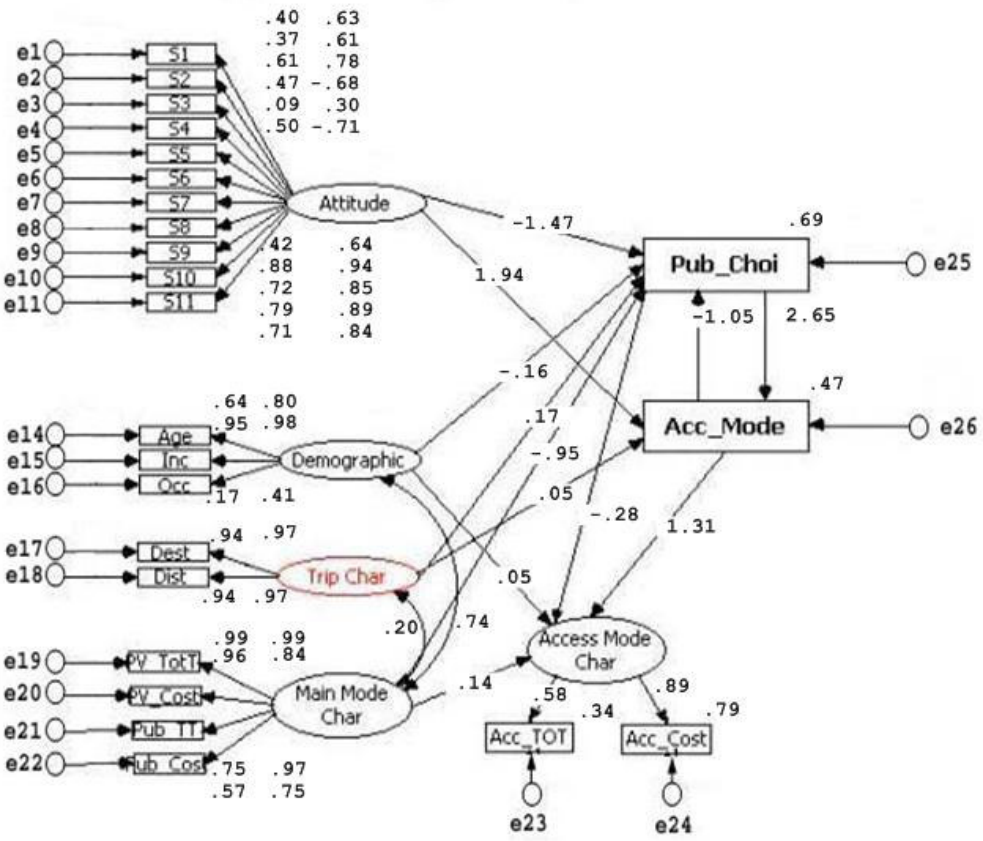

Figure 6 Results of Standardized Model Estimation for Hypothesized Model

4.2 Model, Parameters, and Estimation Summary

From Table 11, there are 58 regression weights, 29 of which are fixed and all of them are estimated. There are 2 covariances and 28 variances, all of which are estimated. In total, there are 112 parameters, 83 of which are to be estimated. The hypothesized model is of a non-

recursive type with the sample size of 1368 and the stability index of 2.788 for Acc_Mode and Pub_Mode variables. The only data which can be worked with in SEM are the observed variables; from this information, this model is an overidentified model with 241 degrees of freedom (Degrees of Freedom = No. of distinct sample moments (324) – No. of distinct parameters to be estimated (83) = 241). The minimum calculated by the maximum likelihood method was achieved; thereby assuring that the estimation process yielded an admissible solution with the chi-square (χ^2) value of 10856.176 together with its degrees of freedom of 316 and probability value of 0.000.

Table 11 Summary of Parameters

	Weights	Covariances	Variances	Means	Intercepts	Total
Fixed	29	0	0	0	0	29
Labeled	0	0	0	0	0	0
Unlabeled	29	2	28	0	24	83
Total	58	2	28	0	24	112

Table 12 Summary of Regression Weights

			Estimate	S.E.	C.R.	P
Pub_Choi	<--	Attitude	-3.062	0.214	-14.325	0.000
Pub_Choi	<--	Demographic	-0.327	0.069	-4.743	0.000
Pub_Choi	<--	Main Mode_Char	0.000	0.000	-9.042	0.000
Acc_Mode	<--	Attitude	4.977	0.619	8.033	0.000
Pub_Choi	<--	Trip Char	0.221	0.036	6.125	0.000
Acc_Mode	<--	Trip Char	0.078	0.038	2.017	0.044
Access Mode_Char	<--	Acc_Mode	178.612	4.999	35.731	0.000
Access Mode_Char	<--	Demographic	16.673	7.398	2.254	0.024
Access Mode_Char	<--	Pub_Choi	-47.866	5.467	-8.756	0.000
Access Mode_Char	<--	Main Mode_Char	0.011	0.003	4.025	0.000
S2	<--	Attitude	1.000			
S1	<--	Attitude	1.060	0.052	20.377	0.000
S3	<--	Attitude	1.310	0.055	24.011	0.000
S4	<--	Attitude	-1.649	0.076	-21.704	0.000
S5	<--	Attitude	0.416	0.040	10.478	0.000
S6	<--	Attitude	-1.616	0.072	-22.323	0.000
S7	<--	Attitude	1.339	0.065	20.765	0.000
S8	<--	Attitude	2.513	0.094	26.782	0.000
S9	<--	Attitude	1.861	0.074	25.254	0.000
S10	<--	Attitude	2.665	0.103	25.895	0.000
S11	<--	Attitude	2.155	0.086	24.926	0.000
Occ	<--	Demographic	1.000			
Inc	<--	Demographic	18144.035	1146.296	15.828	0.000
Age	<--	Demographic	17.810	1.151	15.476	0.000
Dist	<--	Trip Char	1.000			
Dest	<--	Trip Char	4.873	0.131	37.278	0.000
PV_Cost	<--	Main Mode_Char	1.000			
PV_TotT	<--	Main Mode_Char	0.019	0.000	122.822	0.000
Acc_Cost	<--	Access Mode_Char	1.000			
Acc_TOT	<--	Access Mode_Char	0.032	0.001	28.659	0.000
Pub_TT	<--	Main Mode_Char	-0.022	0.000	-53.251	0.000
Pub_Cost	<--	Main Mode_Char	-0.143	0.004	-40.344	0.000
Pub_Choi	<--	Acc_Mode	-0.852	0.116	-7.363	0.000
Acc_Mode	<--	Pub_Choi	3.270	0.238	13.740	0.000

Table 12 shows the summary of regression weights of the model. The test statistic used for test the model's statistical significance of parameter estimates is the critical ratio (C.R.), which represents the parameter estimate divided by its standard error; as such it operates as a z-statistic in testing that the estimate is statistically different from zero. Based on a level of .05, the test statistic needs to be >±1.96 before the hypothesis (that the estimate equals 0.0) can be rejected. The result of the unstandardized solution shown in Table 12 reveals all estimates to be both reasonable and statistically significance; all standard errors appear also to be in good order.

Table 13 Summary of Covariance and Correlation

Covariances			**Estimate**	**S.E.**	**C.R.**	**P**
Main Mode_Char	<-->	Trip Char	408.374	41.486	9.844	0.000
Main Mode_Char	<-->	Demographic	952.788	73.795	12.911	0.000
Correlations			**Estimate**			
Main Mode_Char	<-->	Trip Char	0.200			
Main Mode_Char	<-->	Demographic	0.736			

Eleven from thirteen statements (S1 to S11) are positively significantly related to underlying attitude factors with R^2 ranging from 0.088 to 0.879. The result shows that S12 and S13, which concern with Safety, are insignificantly related and should be eliminated from the model implying that most travelers did not care much about their safety. This is reasonable for the fact that most of them use motorcycle-taxi as their access mode in order to decrease their total travel times without being care much about its potential dangerousness.

Table 14 Summary of Goodness-of-Fit of the Model

Fit Measure	**Model**	**Saturated**	**Independence**	**Macro**
Discrepancy (Chi-Square)	10856.176	0.000	98635.821	CMIN
Degrees of freedom	241	0.000	300	DF
P	0.000		0.000	P
Number of parameters	83	324	24	NPAR
Discrepancy / df	45.046		328.786	CMINDF
Normed fit index	0.890	1.000	0.000	NFI
Relative fit index	0.863		0.000	RFI
Incremental fit index	0.892	1.000	0.000	IFI
Tucker-Lewis index	0.866		0.000	TLI
Comparative fit index	0.892	1.000	0.000	CFI
Parsimony ratio	0.803	0.000	1.000	PRATIO
Parsimony-adjusted NFI	0.715	0.000	0.000	PNFI
Parsimony-adjusted CFI	0.717	0.000	0.000	PCFI
Noncentrality parameter estimate	10615.176	0.000	98335.821	NCP
NCP lower bound	10277.489	0.000	97306.573	NCPLO
NCP upper bound	10959.186	0.000	99371.349	NCPHI
FMIN	7.942	0.000	72.155	FMIN
F0	7.765	0.000	71.935	F0
F0 lower bound	7.518	0.000	71.183	F0LO
F0 upper bound	8.017	0.000	72.693	F0HI
RMSEA	0.180		0.490	RMSEA
RMSEA lower bound	0.177		0.487	RMSEALO
RMSEA upper bound	0.182		0.492	RMSEAHI
P for test of close fit	0.000		0.000	PCLOSE
Akaike information criterion (AIC)	11022.176	648.000	98683.821	AIC
Browne-Cudeck criterion	11025.268	660.072	98684.715	BCC
Expected cross validation index	8.063	0.474	72.190	ECVI
ECVI lower bound	7.816	0.474	71.437	ECVILO
ECVI upper bound	8.315	0.474	72.948	ECVIHI
MECVI	8.065	0.483	72.191	MECVI
Hoelter .05 index	36		5	HFIVE
Hoelter .01 index	38		5	HONE

The Normed fit index (NFI) is 0.890, indicating that the model is 89% better fitting than the null (independence) model. Both of the relative fit index (RFI) and the incremental fit index (IFI) is greater than 0.85 which represents the quite well fit of the model. The R^2 for the public and access mode choice are 0.69, 0.47 respectively. These summary measures of overall model indicate that the model fits moderately well to the data.

On the estimated regression weights on Table 12, the main interest is one on the interaction between the public mode choice and the access mode choice. On the public mode choice equation, the access mode choice variable has a negatively significant coefficient (-0.852), while on the access mode choice equation, the public mode choice variable has a positively significant coefficient (3.270). This indicates that the travelers' access mode choices are influenced and affected by their public mode choice. Travelers are more likely to make a decision on the public choice prior to making a decision of which access modes they will use. Any changes in public choices will immediately affect their access mode choice. Also, this indicates an importance of including an access mode variable on the public mode choice equation.

In addition to observed socio-demographics such as gender, age, income, and occupation, the person's attitude and perception have an important role on public and access mode choice. The S4 and S6, which are the representatives of the attitude toward travel cost and comfort respectively, have negatively related to the commuter's choices. These indicate that a person considers being on-time or travel time and flexibility rather than travel cost and comfort. Thus, latent attitude variables are as important determinants as observed individual characteristics.

5. APPLICATION

5.1 Effect of Distance on Access Mode Choice

The following chart presents the relationship between the distances from the commuters' home to the public stops and their access mode choice. From the observation, the maximum walking distance of the commuters in the study area is 570 meters, while 800 and 2,350 meters are the maximum distances for bicycle and Song Taew respectively.

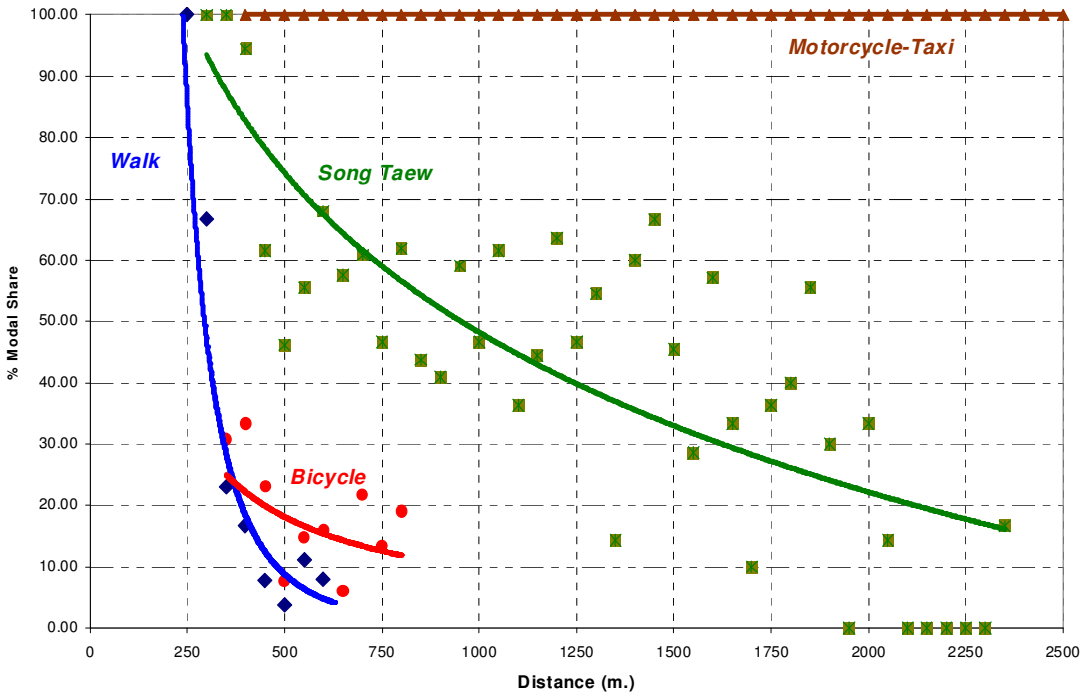

Figure 7 Relationships between Distance and Access Mode Choice

5.2 Introduction of New Access Mode

The lacking of efficient access mode obviously decreases the quality of commuters' travel. Some public mode such as rail was ignored by travelers in this study area due to its inconvenient accessibility. To enhance the travel's quality, a new access mode should be introduced. In this study, a two-month shuttle bus project was adopted by the resident owner to increase the residents' satisfaction. Ten shuttle buses were shuttling from the study area (Muang Thong Thani residential area) to the Laksi railway station with a one-direction trip distance of about four kilometers. The service was divided into two period to serve both morning and evening peak hour periods. The morning service normally serves from 06.00 to 09.00AM and the evening service usually run from 16.00 to 19.00. The bus fare is 10 Baht per trip together with alternatives of the 10% discount weekly and 25% discount monthly coupon. Each bus capacity is 30 seated passengers allowing no standing passenger. From the observation in the first two-week of the project, every bus was almost fully occupied reflecting the travelers' interests.

5.2.1 The Before-and-After Study

To evaluate the success of the project and the users' satisfaction, the before-and-after study was employed. The 250 before-study questionnaires were distributed to respondents asking about their demographics, opinion and attitude toward project, and previous trip characteristics prior to the provision of shuttle bus. After finishing the pilot project, the 250 after-study questionnaires were then sent to the houses of the same respondents who answered to the before-study questionnaires. The results of the before-and-after questionnaire surveys were presented in the following tables.

Table 15 Summary of Before-Study Statistics

Before	Description	Mean		Std. Deviation	Variance
		Statistic	Std. Error		
BAcc-TT	Access total time	20.16	0.69	10.98	120.46
BAcc-TC	Access total cost	6.60	0.24	3.81	14.50
Bpub-TT	Public total time	96.66	1.87	29.53	872.03
Bpub-TC	Public total cost	12.42	0.47	7.37	54.26
BTOTT	Total travel time	**116.82**	1.72	27.19	739.55
BTC	Total travel cost	**19.02**	0.48	7.57	57.37

Table 16 Summary of After-Study Statistics

After	Description	Mean		Std. Deviation	Variance
		Statistic	Std. Error		
AAcc-TT	Access total time	44.74	0.39	6.13	37.58
AAcc-TC	Access total cost	10.00	0.00	0.00	0.00
Apub-TT	Public total time	54.52	0.33	5.22	27.28
Apub-TC	Public total cost	5.00	0.00	0.00	0.00
ATOTT	Total travel time	**99.26**	0.51	8.10	65.61
ATC	Total travel cost	**15.00**	0.00	0.00	0.00

As seen from Table 15, the average total travel time and the average total travel cost of travelers before the provision of shuttle bus were 116.82 minutes and 19.02 Baht respectively, while those of the same travelers after running the shuttle bus project were 99.26 minutes and 15.00 Baht respectively. The average total travel time was obviously decreased for 17.56 minutes per trip (15.03%), while the average total travel cost was dramatically decreased for 4.02 Baht per trip (21.14%). These indicate that the provision of the shuttle bus as a new access mode attract travelers to use rail as their new public mode and thus help reduce both of their total travel time and cost. Access total time increased after the provision of shuttle bus, because some changed access points from near bus stop to far railway station.

5.2.2 Test of Statistical Significance

It is necessary to determine whether there is a significant difference between the mean total travel time and cost of before and after studies to indicate how much good the provision of shuttle bus improves the overall travel quality. This is done by comparing the absolute difference between sample means against the product of the standard deviations of the difference in means and the factor Z for a given confidence level. If the absolute difference between the sample means is greater, it can then be concluded that there is a significant difference in sample means at that specific confidence level (Garber, 1997). The following equation is used to determine the significance.

$$\frac{\left|\overline{X}_a - \overline{X}_b\right|}{\hat{S}} > t_{\frac{\alpha}{2}} \tag{1}$$

$$\hat{S} = \sqrt{\frac{S_b^2}{n_b} + \frac{S_a^2}{n_a}} \tag{2}$$

, where $\overline{X}_b$ = mean speed of before-study
$\overline{X}_a$ = mean speed of after-study
$t_{\alpha/2}$ = the level of t-distribution with level of significance (±1.96 at 95%)
$\hat{S}$ = standard deviation of difference in means
S_b^2 = variance of before-study
S_a^2 = variance of after-study

As for the equation (1) and (2), the statistical tests are 9.785 and 8.392 for total travel time and total travel cost respectively, which are greater than ±1.96 at the 95% confidence level. These indicate that there are significant difference the sample means of both total travel time and cost proving that the provision of shuttle bus significantly help reduce travelers' total travel time and cost leading to the improvement of the overall travel's quality. Furthermore, the following table is the summary of travelers' opinion toward shuttle bus mode.

Table 17 Summary of Travelers' Opinion

Opinion	Frequency		Percent	
	Before	After	Before	After
Will surely use	0	94	0.00	37.60
May Use	52	73	20.80	29.20
No Opinion	74	17	29.60	6.80
May not use	79	31	31.60	12.40
Will surely not use	45	35	18.00	14.00
Total	250	250	100.00	100.00

In the before-study, the results show that there were only 52 people may use the shuttle bus (20.8%) and no one will surely use it, while 74 respondents had no opinion (29.6%) showing that there were at least 49.6% of respondents will not use the shuttle bus. Two weeks later, the after-study of travelers' opinion shows the obvious changes. The number of people who will surely use this mode is dramatically increased from 0 to 94 (0% to 37.6%). The number of people who have no opinion is decreased from 74 to 17 (29.6% to 6.8%). For the overall picture, this study shows that the amounts of people who will surely or may use the shuttle bus are increased for they consider it as their new and efficient access mode.

6. CONCLUSION

The structural equations analysis can be used to reveal and examine the decision making process on public and access mode choice. As an application example, the Muang Thong Thani data shows that (1) the decision on public mode choice is made first, then the access mode is chosen for given public mode choice, and (2) personal attitude and perception are

indeed important determinants of mode choices.

It also reveals that people in the study area prefer faster transport mode to cheaper or safer mode. Moreover, such modes need to approach the characteristics of private transport rather than those of fixed routes and fixed scheduled service. As a result, the motorcycle-taxi service as a demand responsive access mode and the van service as a semi-demand responsive public mode are popular among the public riders, particularly in this area. The main role of motorcycle-taxi for short hauls is shuttling people from their homes to public stops, while the main role for long hauls is to beat the traffic during times of congestion.

The before-and-after study shows that the shuttle bus project significantly helps improve the travel's quality by decreasing the total travel time and cost. This project is warmly welcomed by the commuters considering it as their new and efficient access mode leading to the enhancement of their lives' quality.

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