MODAL CHOICE MODEL BETWEEN CAR AND BUS A CASE STUDY OF THAILAND

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abstract: The dicriminant analysis is conducted to determine the characteristics of transport mode choice for the work trip at Nava Nakorn, one of three satellite towns around the Bangkok metropolitan area to alleviate the infamous traffic congestion. The final dicriminant function involves six different variables: car demand ratio, sex, education level, leave home time difference, relative difference of total cost, and relative difference of in-vehicle time. With the obtained function as an input for the logistic model, a car restraint model is established to predict the probability of car users at Nava Nakorn. A policy testing is, thus, carried out to forecast the efficiency of the policy of discouraging the car users.

1. INTRODUCTION

There are two general basic solutions can be used to solve traffic congestion problems: change demand to meet system capability or increase system capacity to meet demand. It is believed that the supply of road space will create its own demand. The number of cars will still increase to fill up the road space available for it. Building more roads may help in the short term , but the increase on auto ownerships will fill up the road space in the long term.(Meyer et al. 1984) This study focuses on analyzing the car restraint modelling of car users by the method of behavioral travel demand model. The dicriminant analysis was used to discriminate between the two types of choice behaviors (car users and bus users) and a probabilistic extension was applied to determine the probability of car users and bus users. Hypothetical policies for restraining the car usage were assumed to forecast percentage of modal shift from car users to bus users.

2. DATA COLLECTION AND SURVEY RESULT

Nava Nakorn was used as a study area due to that it designed to be a self supporting community in response to a government policy for creating a satellite town of Bangkok. Nava Nakorn is located at Klong Luang District in Phathumthani Province. Nava Nakorn cover approximately 6,000 rai of land and have 50,000 people live inside. Nava Nakorn is divided into 3 parts industrial zones, residential zones and commercial zones. In discrete choice analysis, there are three ways to perform the sampling size. These are simple random sampling, stratified random sampling, and cluster sampling. In this study the simple random sampling was selected. In simple random sampling, a sample is drawn in such a way that all elements in the population have an equal and constant chance of being drawn and all possible samples have an equal chance of being drawn. Simple random sampling has a few advantages over other sampling methods. It is easy to understand, is commonly used (making it easier to compare results with other surveys), and allows a designer to select a sample with no population data besides a frame. The resulting sample from simple random sampling will be independent and identical distribution.

Travel is a function of human activity and is habitual. As a habit, it tends to be repetitive and the repetition occurs in a definite pattern. Because patterns of movement exhibit these characteristics, it is not necessary to obtain travel information from all residents in a city area under study (Brand 1976; Daganzo 1980). In this study 80 questionnaires will be used for pilot study and 1,000 questionnaires will be used for data collection. In this study personal interview questionnaire design will be selected. Staffs will make an interviewing in the study area. The data are classified into two categories, respondent and household characteristic data and journey data. The respondent and household characteristic data of the travellers includes the ages, sexes, household size, monthly income, car ownerships, number of licenses per household and mode of travel for their work trip. Journey data include the travel time, walking time, waiting time, in-vehicle travel time and travel cost. A pilot survey was introduce in this study, about 80 questionnaires used to check the validity of the questionnaire and to conduct a pre-survey on the characteristics of the study area. Tables 1. and 2. provide a summary of the results of the pilot survey.

Table 1. Distribution of Working Place Location by Home Place Location

HOME LOCATION	WORKING PLACE LOCATION		
	INSIDE	OUTSIDE	TOTAL
INSIDE	56(70%)	8(10%)	64(80%)
OUTSIDE	16(20%)	-	16(20%)
TOTAL	72(90%)	8(10%)	80(100%)

Table 2. Distribution of Best Alternative Mode by Normal Mode

NORMAL	BEST ALTERNATIVE MODE					
	CAR	TRAIN	BUS	TAXI	MOTORCYC	TOTAL
CAR	-	2(2.5%)	18(22.5%)	1(1.3%)	2(2.5%)	23(28.8%)
BUS	51(63.75%)	-	-	-	-	51(63.8%)
MOTORCYCLE	5(6.25%)	-	-	-	-	5(6.3%)
SONG TAWE	1(1.25%)	-	-	-	-	1(1.3%)
TOTAL	57(71.3)%)	2(2.5%)	18(22.5%)	1(1.3%)	2(2.5%)	80(100%)

Because Nava Nakorn was designed to be the self supporting community, most of the work trips (70%) is intra-zonal work trips as shown in Table 1. From Table 2., 64 % of the respondents use bus for the normal mode and car for the best alternative mode and 23 % of the respondents use car for normal mode and bus for best alternative mode. Results from the pilot survey thereby let this study to include only intra-zonal trips and the modal choice as only bus and car.

After studying the characteristics of the study area, a total of 1,000 questionnaires was collected. From Table 2., 549 respondents used car for the normal mode and bus for the best alternative mode, 207 respondents used bus for the normal mode and car for the best alternative mode. The analysis included 756 (549+207) questionnaires out of 1,000 questionnaires because some data were incorrect. The result of the survey was revealed into two parts : respondent and household characteristic data and journey data.

2.1. Respondent and Household Characteristic Data

Following is the information collected for respondent and household characteristics:

- Sex – The proportion of the surveyed respondents was 64% males to 36% female. The influence on the modal choice from the sex of the trip maker may be the preference in using the car and the perception for comfortable characteristics. A man may have a higher income to pursue the higher preference and comfortable perception in using the car than a woman.
- Age – Most respondents are working in the range of 31-50 years old. The age affects the choice of mode when the elder people used car more than the younger people.
- Household size – The result of the survey showed that most respondent's households have three members. The total number of persons in the household is not logically related to choice of mode. The influence on modal choice from the household composition may be disaggregate into certain subgroups. For example, the number of students in the household may influence modal choice because parent will take the car to work and take the children to school.
- Income – Majority of the total respondents have more than 15,000 baht for their monthly income and 20,001-30,000 baht for their family monthly income. The income may influence modal choice by higher income people, a higher marginal value of time then he trend to use car.
- Occupation – Most of the respondents worked for private company.
- Education – Most respondents have the education level was technical school-diploma degree. The respondents with higher education level is positively related to the probability of taking the car to work.
- Car ownership – Most of the respondents (93%) have only one car for their household. The car demand ratio (CDR) is the variable which represents the number of car ownership and number of driving licenses in the household. It is the ratio of the number of driving licenses in the household to the number of cars in the household. The probability of car usage may be negatively to the car demand ratio.
- Driven licenses – Most of the respondents (71%) have one driving licenses per household and 29% of the respondents have two driving licenses per household.

2.2. Journey Data

For journey data , time, cost, and distance data were collected as follow :

- Travel cost – In car section; car parking cost, car gasoline cost, car maintenance cost, car insurance cost and employer contribution to car park cost were collected.
- Travel time – In the car section, car in-vehicle time, car parking time and car walking time were collected.

- Travel distance – It was coded as a number of kilometer that a traveller travelling from place of residence to work place location in one day. A probability of using car may be positively related to the travel distance, i.e. as the trip time lengthens the discomfort of the bus is increasingly.
- Leave home time – Leave home time of car and bus were collected. Leave home time difference (LHTD) was formated. It is a difference between the time a respondent departing in the morning by car and the time the person travelling by a bus. A probability of using a car is positively related to the difference between the perceived departure times of the two relevant modes (car departure time minus bus departure time). The summary of journey data for car and bus section were shown in Table 3.

Table 3. Journey Data of the Round Trip to and from Work

	CAR	BUS
Invihical Time	36.2 min	42.22 min
Excess Time	10.42 min	23.02 min
Total Time	46.62 min	65.24 min
Total Cost	85.56 baht	26.25
Leave Home Time	19.60 min	
Distance	18.87 km	

3. ANALYSIS AND DISCUSSION

The discriminant analysis was used to discriminate between the two types of choice behaviour (car/bus users), with the additional constraints, the model developed from the discriminant analysis will predict the future behaviour. A probabilistic extension model was selected as the analytical tool to find the transformation of the probability with values from $-\alpha$ to $+\alpha$, to restrict the probability values in the range 0 to 1. The policy testing was used to find the mode shift from car to bus usage.

3.1. Discriminant Analysis

There were two major steps in the discriminant analysis.(Ben-Akiva 1975, 1985) The first one only considered travel time and travel cost formation variables for the analysis. The second step was to comprise the respondent and household characteristic variables. Statistics used to determine the importance of each variable in the model was "Wilk's Lambda". In this model the variable with lesser Wilk's Lambda value was more important. Eigen values and percent of grouped cases correctly classified were used to justify the importance of each model. Models with greater eigen value and percent of grouped cases correctly classified are better than a lesser one. It is also important to consider the effects of the small changes in the independent variables on the dependent variable. The sign of the coefficient should be compatible with the expectation. Changes in the independent variables will cause anticipated effects on the dependent variable. In the consideration of the total time difference as the variable, the construction of this variable meant that the following relationship exists:

$$z = \alpha - \beta \, (BTTO - CTTO) \tag{1}$$

where : z = discriminant score
BTTO = bus total travel time
CTTO = car total travel time
α, β = constant parameters

Within this relationship, four changes can be considered, upward or downward changes in bus total travel time (*BTTO*) and car total travel time (*CTTO*). If bus total travel time should rise, then the discriminant score should be moved close to the car centroid; if bus total travel time should fall, then the discriminant score should be moved close to the bus centroid; if car total travel time should rise, then the discriminant score should be moved closer to the bus centroid; if car total travel time should fall, then the discriminant score should be moved closer to the car centroid.

The following models were composed of the formation variables and raw variables which reflect different expectation about the way in which the individual traveller assesses information of system characteristics. The first four models that comprised of the total travel time and total travel cost formation variables were shown below.

MODEL 1.
Model 1. was choosen as the starting point of the analysis. It was based on the premise that travellers will use the differences in the total travel times and total travel costs to make their comparisons to arrive at their mode-choice decisions. To illustrate, a traveller may consider using between a bus or a car by considering both travel time and momentary cost. The traveller may faced with the following situation : a bus takes 5 minutes longer than the car, but the former costs 10 baht less. The traveller must then make his/her rational decision. The result of the discriminant analysis for Model 1. is shown below.

Table 4. Result of Discriminant Analysis for Model 1.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	TTD TCD	0.52049 0.78702	0.0682	CORRECT
2	TCD	0.49378	-0.0154	CORRECT
		CONSTANT	-0.359	

N.B. 1) TCD = Total travel time difference (CCTO-BCTO)
TTD = Total travel cost difference (BTTO-CTTO)
2) Eigen value = 1.0252
3) Percent of grouped cases correctly classified = 87.15%

MODEL 2.
It may be expected that travelers will use the total travel times and total travel costs in ratio forms to make their mode-choice decisions. To illustrate this, travellers may choose between a bus or a car in this situation : the bus take twice as long as the car to go to the destination, but bus fare is only one-third of the price of gasoline to fuel the car to go to the same destination. The result of the discriminant analysis for Model 2. was shown below.

Table 5. Result of the Discriminant Analysis for Model 2.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	TTR TCR	0.8111 0.9923	1.637	CORRECT
2	TCR	0.8019	-0.0944	CORRECT
		CONSTANT	-2.1148	

N.B. 1) TTR = Total time ratio (BTTO/CTTO)
TCR = Total cost ratio (CCTO/BCTO)
2) Eigen value = 0.247
3) Percent of grouped cases correctly classified = 82.60%

MODEL 3.

It may be expected that the traveler use the total travel times and total travel costs in the form of log of ratios for comparing the mode-choice decision. The result of the discriminant analysis for Model 3. was shown below.

Table 6. Result of Discriminant Analysis for Model 3.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	LTT LTC	0.5714 0.9351	8.966	CORRECT
2	LTC	0.5309	-1.933	CORRECT
		CONSTANT	-0.3757	

N.B. 1) LTC = Log ratio of total cost (log (CCTO/BCTO))
LTT = Log ratio of total time (log (BTTO/CTTO))
2) Eigen value = 0.8877
3) Percent of grouped cases correctly classified = 89.24%

MODEL 4.

It may be expected that the traveller use the total travel times and total travel costs in terms of the differences relative in designing mode choice. Two situations were given. In the frist situation, travel time for A takes 60 minutes and travel time for B to the same destination can take 90 minutes. By travelling to the same destination, situation 2 presents travel time for A and B to consume 100 and 150 minutes respectively. The two situations show that travel time difference between travellers A and B is 30 minutes. It seems reasonable that a total travel time difference of 30 minutes in a two-hour journey is the same with a one-hour journey. However, in relative difference form, the shorter total travel time difference will be valued more highly.

	SITUATION 1.	SITUATION2.
TA	60	120
TB	90	150
ΔT	30	30
$\Delta T/((TA+TB)/2)$	0.40	0.22

With this example in mind, the discriminant analysis was carried out for the data collected. The result of the discriminant analysis for Model 4. was shown below.

Table 7. Result of Discriminant Analysis for Model 4.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	TDREL CDREL	0.5434 0.8963	4.188	CORRECT
2	CDREL	0.4938	-1.443	CORRECT
		CONSTANT	0.0578	

N.B. 1) TDREL = Relative difference of total travel time ((BTTO-CTTO)/(BTTO+CTTO)/2)
CDREL = Relative difference of total travel cost ((CCTO-BCTO)/(CCTO+BCTO)/2)
2) Eigen value = 1.0373
3) Percent of grouped cases correctly classified = 89.40%

It is revelled that, for the four models above, Model 4., which was in a relative difference form, was the best model. It has greater eigen value and percent of grouped cases correctly classified. The relative difference of total time variable (TDREL) and relative difference of total cost variable (CDREL) will be used for the next models. In-vehical and excess time variables will also be included. Models 5, 6, 7, 8, as will be shown below will present a relative difference form of total time and cost variables from Model 4. with the inclusion of the in-vehical and excess time variables. Models number 5.1, 6.1, 7.1, 8.1 will present only variables that have a rationality sign with their expectation from Models 5, 6, 7, 8.

MODEL 5.

Model 5. involved the same basic data set as in Model 4. with the addition of in-vehical time and excess time in difference forms. The result of the discriminant analysis for Model 5. is shown below.

Table 8. Result of Discriminant Analysis for Model 5.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	XSTD CDREL TDREL IVTD	0.4124 0.8963 0.5434 0.9765	0.0659	CORRECT
2	CDREL TDREL IVTD	0.4 0.4092 0.4124	-1.0675	CORRECT
3	TDREL IVTD	0.3939 0.4	2.235	CORRECT
4	IVTD	0.3848	-0.3697	NOT CORRECT
		CONSTANT	-0.27	

N.B. 1) TDREL = Relative difference of total travel time ((BTTO-CTTO)/(BTTO+CTTO)/2)
CDREL = Relative difference of total travel cost ((CCTO-BCTO)/(CCTO+BCTO)/2)
IVTD = In-vehical time difference (BTIN-CTIN)
XSTD = Excess time difference (BTEX-CTEX)
2) Eigen value = 1.5900
3) Percent of grouped cases correctly classified = 92.85%

MODEL 5.1.

Model 5.1. uses the same basic data set as Model number 5. with the exclusion of in-vehical time difference (IVTD). The result of the discriminant analysis for Model 5.1. is shown below.

Table 9. Result of discriminant analysis for Model 5.1.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	XSTD CDREL TDREL	0.4124 0.8963 0.5434	0.0853	CORRECT
2	CDREL TDREL	0.4 0.4092	-0.8377	CORRECT
3	TDREL	0.3939	0.9797	CORRECT
		CONSTANT	-0.5448	

N.B. 1) TDREL = Relative difference of total travel time ((BTTO-CTTO)/(BTTO+CTTO)/2)
CDREL = Relative difference of total travel cost ((CCTO-BCTO)/(CCTO+BCTO)/2)
XSTD = Excess time difference (BTEX-CTEX)
2) Eigen value = 1.5388
3) Percent of grouped cases correctly classified = 91.92%

MODEL 6.

Model 6. had the same basic data set as in Model 4. with the addition of in-vehical time and excess time in ratio forms. The result of the discriminant analysis for Model 6. was shown below.

Table 10. Result of Discriminant Analysis for Model 6.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	TDREL CDREL IVTR XSTR	0.5364 0.9008 0.9925 0.7962	5.134	CORRECT
2	CDREL IVTR XSTR	0.4802 0.5039 0.5361	-1.5685	CORRECT
3	IVTR XSTR	0.4483 0.4796	-0.5467	NOT CORRECT
4	XSTR	0.4452	-0.0461	NOT CORRECT
		CONSTANT	0.7468	

N.B. 1) TDREL = Relative difference of total travel time
((BTTO-CTTO)/(BTTO+CTTO)/2)
CDREL = Relative difference of total travel cost
((CCTO-BCTO)/(CCTO+BCTO)/2)
IVTR = In-vehical time ratio (BTIN/CTIN)
XSTR = Excess time ratio (BTEX/CTEX)
2) Eigen value = 1.2461
3) Percent of grouped cases correctly classified = 89.80%

MODEL 6.1.

Model 6.1. used the same basic data set as Model 6. with the exclusion of in-vehical time ratio (IVTR) and excess time ratio (XSTR). The result of the discriminant analysis for Model 6.1. was shown below.

Table 11. Result of Discriminant Analysis for Model 6.1.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	TDREL CDREL	0.5364 0.8963	4.188	CORRECT
2	CDREL	0.4908	-1.443	CORRECT
		CONSTANT	0.0578	

N.B. 1) TDREL = Relative difference of total travel time
CDREL = Relative difference of total travel cost
((CCTO-BCTO)/(CCTO+BCTO)/2)
2) Eigen value = 1.0373
3) Percent of grouped cases correctly classified = 89.40%

MODEL 7.

Model 7. used the same basic data set as in Model 4. with the addition of in-vehical time and excess time in the log of ratio forms. The result of the discriminant analysis for model 7. is shown below.

Table 12. Result of Discriminant Analysis for Model 7.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	LXST CDREL TDREL LIVT	0.4129 0.8990 0.5350 0.9735	1.836	CORRECT
2	CDREL TDREL LIVT	0.3975 0.4079 0.4111	-1.1237	CORRECT
3	TDREL LIVT	0.3889 0.3959	2.6427	CORRECT
4	LIVT	0.3834	-2.7841	NOT CORRECT
		CONSTANT	-0.0728	

N.B. 1) TDREL = Relative difference of total travel time ((BTTO-CTTO)/(BTTO+CTTO)/2)

CDREL = Relative difference of total travel cost ((CCTO-BCTO)/(CCTO+BCTO)/2)

LIVT = Log ratio of in-vehical time (log (BTIN/CTIN))

LXST = Log ratio of excess vehical time (log (BTEX/CTEX))

2) Eigen value = 1.6082

3) Percent of grouped cases correctly classified = 93.32%

MODEL 7.1.

Model 7.1. used the same basic data set as in Model 7. with the exclusion of log of in-vehical time (LIVT). The result of the discriminant analysis of Model 7.1. is shown below.

Table 13. Result of discriminant analysis for Model 7.1.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	LXST CDREL TDREL	0.4127 0.9008 0.5365	2.5626	CORRECT
2	CDREL TDREL	0.3976 0.4080	-0.9384	CORRECT
3	TDREL	0.3888	1.1839	CORRECT
		CONSTANT	-2.005	

N.B. 1) TDREL = Relative difference of total travel time
((BTTO-CTTO)/(BTTO+CTTO)/2)
CDREL = Relative difference of total travel cost
((CCTO-BCTO)/(CCTO+BCTO)/2)
LXST = Log ratio of excess vehical time
(log (BTEX/CTEX)
2) Eigen value =1.572
3) Percent of grouped cases correctly classified = 93.74%

MODEL 8.

Model 8. used the same basic data set as in Model 4. with the addition of in-vehicle time and excess time in relative difference forms. The result from the discriminant analysis of Model 8. is shown below.

Table 14. Result of Discriminant Analysis for Model 8.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIEN T	SIGN
1	TDREX CDREL TDREI TDREL	0.3615 0.8963 0.9761 0.5434	2.0717	CORRECT
2	CDREL TDREI TDREL	0.3514 0.3597 0.3615	-0.6398	CORRECT
3	TDREI TDREL	0.349 0.3510	1.0299	CORRECT
4	TDREL	0.3475	-0.922	NOT CORRECT
		CONSTANT	-0.4804	

N.B. 1) TDREL = Relative difference of total travel time
((BTTO-CTTO)/(BTTO+CTTO)/2)
CDREL = Relative difference of total travel cost
((CCTO-BCTO)/(CCTO+BCTO)/2)
TDREX = Relative difference of excess time
((BTEX-CTEX)/(BTEX+CTEX)/2)
TDREI = Relative difference of in-vehical time
((BTIN-CTIN)/(BTIN+CTIN)/2)
2) Eigen value = 1.8775
3) Percent of grouped cases correctly classified = 94.57%

MODEL 8.1.

This model used the same basic data set as Model 8. with the exclusion of relative difference of total time (TDREL). The result from the discriminant analysis of Model 8.1. is shown below.

Table 15. The result of Discriminant Analysis of Model 8.1.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	TDREX CDREL TDREI	0.3615 0.8963 0.9761	1.8117	CORRECT
2	CDREL TDREI	0.3514 0.3597	-0.7066	CORRECT
3	TDREI	0.349	0.4641	CORRECT
		CONSTANT	-0.4764	

N.B. 1) CDREL = Relative difference of total travel cost, ((CCTO-BCTO)/(CCTO+BCTO)/2)
TDREX = Relative difference of excess time, ((BTEX-CTEX)/(BTEX+CTEX)/2)
TDREI = Relative difference of in-vehical time, ((BTIN-CTIN)/(BTIN+CTIN)/2)
2) Eigen value = 1.8653
3) Percent of grouped cases correctly classified = 94.57%

As a result of the discriminant analyses on Models 5.1, 6.1, 7.1, 8.1, Model 8.1 which is in a relative difference form of in-vehical time, excess vehical time and total cost, showed to be the best model. It has greatest eigen value and percent of grouped cases correctly classified. The relative difference of excess time (TDREX), relative difference of total cost (CDREL) and relative difference of in-vehical time (TDREI) will be used for the next model, Model 9. Model 9. presented a variable from Model 8.1. It also included leave home time difference (LHTD), and the characteristics of the respondents and the households.

MODEL 9.

The value of leave home time difference between car and bus journey may have a significant influence in the decision-making process. As mentioned above, this variable plus the respondents and the household's characteristics can be included in this model. Table 16. shows only the most important variables from each steps. It has the smallest Wilk's Lambda value in that step.

Table 16. Result of discriminant analysis of Model 9.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	CDR	0.202	4.479	CORRECT
2	SEX	0.18	0.8924	CORRECT
3	EDU	0.176	-0.3816	CORRECT
4	LHTD	0.173	-0.0058	CORRECT
5	CDREL	0.1711	0.4253	CORRECT
6	TDREI	0.1698	-0.4038	CORRECT
7	NWHO	0.1689	0.1824	NOT CORRECT
8	D	0.1683	0.0022	NOT CORRECT
9	AGE	0.1681	0.0654	NOT CORRECT
		CONSTANT	-6.0087	

N.B. 1) Eigen value = 4.9511
2) Percent of grouped cases correctly classified = 95.88%

MODEL 9.1.
Six variables were presented in this model namely : car demand ratio (CDR), sex (SEX), education level (EDU), leave home time difference (LHTD), relative difference of total cost (CDREL) and relative difference of in-vehicle time (TDREI). Table 17 shows only the most important variables from each steps. It has the smallest Wilk's Lambda value in that step.

Table 17. Result of discriminant analysis for Model 9.1.

STEP	VARIABLES	WILK'S LAMBDA	COEFFICIENT	SIGN
1	CDR	0.202	4.496	CORRECT
2	SEX	0.18	0.9078	CORRECT
3	EDU	0.176	-0.396	CORRECT
4	LHTD	0.173	-0.0058	CORRECT
5	LEL	0.1711	0.4615	CORRECT
6	TDREI	0.1698	-0.4332	CORRECT
		CONSTANT	-5.2542	

N.B. 1) Eigen value = 4.8889
2) Percent of grouped cases correctly classified = 95.88%

Model 9.1 can be written as a discriminant function as shown below :

$$= 4.496(CDR) + 0.9078(SEX) - 0.396(EDU) - 0.006(LHTD) + 0.4615(CDREL) - 0.4332(TDREI) - 5.254$$

3.2. A Probabilistic Extension

In mode choice analysis, the aim is not so much on classifying individuals but more on predicting the probability of an individual's action. The sum of such probability may be used as an estimate of the proportion of the population taking a given action. The probability of using a bus by the sampled commuter can be derived by adding t (t = ln (546/207) = 0.9699) to the discriminant scores, thus :

$$P(\text{ using bus }) = \frac{e^{z+t}}{1+e^{z+t}} \tag{2}$$

The individual probabilities were calculated, and then the mean probability can be derived. The sampled respondent has an 55% probability of being a bus-user and 45% probability of being a car-user.

3.3. Policy Testing

Most transportation planning has been carried out to predict the impact of alternative on the transportation system. It is possible to examine the effect of policies on the modal split, by changing the value of the relevant variables for each individual in the sample and re-computing the mean probability. One of the raw variables (leave home time difference (LHTD)) and two of the formation variables (relative difference of total cost (CDREL) and relative difference of in-vehical time

(TDREI)) were used to predict mode shift. CDREL consists of car insurance cost (CCIN), car park cost (CCPK), car gaoline cost (CCGA), bus ticket cost (BCTK), and bus feeder mode cost (BCMO). TDREI consists of bus in-vehicle time (BTIN), car in-vehicle time (CTIN).

The utilization of utility model for prediction purposes was shown by examples outlined in Table 18. For example, if respondents can decrease their leave home time difference by 25 minutes, the probability of using bus can be predicted as follows :

$$P\ (\ using\ bus\ ) = \frac{e^{z \cdot t}}{1 + e^{z \cdot t}} \tag{3}$$

where:

$$z = 4.496(CDR) + 0.9078(SEX) - 0.396(EDU) - 0.006(LHTD - 25) + 0.4615(CDREL) - 0.4332(TDREL) - 5.254$$

$t = 0.9699$

The probabilities are summed for all the individual data; thus, the mean probabilty can be obtaineded. The percentage of mode shift from car to bus can be predicted by substracting the previous probability of using bus (0.55). The purpose of car restraint model is to restrain car usage. Table 18. showed the modal shift from cars to buses. The greatest shift was observed by decreasing 40% bus in-vehical time and at the same time increasing 30% car in- vehical time. An equal percentage of shift was also observed by decreasing leave home time difference and bus in-vehical time by 20 minutes and 30%, respectively and at the same time increasing by 20% the car gasoline cost. A great percentage (5%) of modal shift from cars to buses was also manifested by decreasing bus in-vehical time by 50%. These information highlight the importance of time element as a determinant for modal shift. These large modal shifts resulting from introducing such policies can reflect people's perception in implicit cost involved in travelling. People may care more about travel time than travel cost (monetary). Reducing travel time is an important factor even if commuters are willing to pay more to get to their destination.

The first four policies are shown in Table 18., indicating that increasing car insurance by 20%, increasing car parking cost and increasing gasoline cost by 10% have very limited effect on the modal shift. These four policies primarily focus on increasing cost per car parking space, insurance and gasoline. However, increasing car travel cost will have no effect on people who have their own cars because they can offer for those increasing cost.

The hypothetical scenarios created by the 14 policies were shown in Table 18. It is important that car restraint policies consider the significance of travel time. Policies should be drawn based on pratical experiences of people. For instance, in considering leave home time difference as a policy, the modal shift from car to bus may be encouraged by increasing the frequency or even number of buses passing along a certain route; for in-vehical time, bus lanes should be built such that buses have the priority in passing through traffics.

Table 18. Predicted effect of various policies on mode shift from car to bus from the journey to and from work.

POLICY	PERCENT USAGE				MODE SHIFT
	CAR		BUS		
	BEFORE	AFTER	BEFORE	AFTER	
Increase car cost insurance by 20%	45	44	55	56	1%
Incease car parking cost by 10 baht	45	44	55	56	1%
Incease car parking cost by 20 baht	45	43	55	57	2%
Increase car gassoline cost by 10%	45	44	55	56	1%
Decrease bus ticket cost by 30%	45	43	55	57	2%
Decrease bus feeder mode cost by 10 baht	45	42	55	58	3%
Decrease bus in-vehical time by 20%	45	43	55	57	2%
Decrease bus in-vehical time by 50%	45	40	55	60	5%
Increase car in-vehical time by 30%	45	43	55	57	2%
Decrease leave home time difference by 5 min	45	44	55	56	1%
Decrease leave home time difference by 15 min	45	43	55	57	2%
Decrease leave home time difference by 25 min	45	42	55	58	3%
Decrease bus in-vehical time by 40% and increase car in-vehical time by 30%	45	39	55	61	6%
Decrease leave home time difference by 20 min and decrease bus in-vehical time by 30% and increase car gasoline cost by 20%	45	39	55	61	6%

4. CONCLUSION AND RECOMENDATION

In this study, pilot survey was used to find out the characteristics of Nava Nakorn. Variables were designed based upon respondents and households characteristic and journey data. The formation variables of travel time and travel cost from journey data were designed for each model. The models which composed of travel time and travel cost formation variables were checked by the discriminant analysis in the beginning. The best model which composed of travel time and travel cost formation variables included the respondent and household characteristic variables to develop the final model. Probability extension was used to find the probability of car users and bus users. Policy testing was used to find out the effect of policy on the modal split. Based on the results and analyses, the following characteristics of respondents, car restraint model, determinants of transport mode choice, probability extension and policy testing can be drawn.

For further study and indepth investigation, the following statements are the recommendation that could help to improve the modal split analysis and policy research in solving transportation problems. The car restraint model from this study should be implemented to any similar study zone areas to check the efficiency of model. The implementation of car restraint model to another zone areas can be done by collecting the data of six determinant variables and find the percentage correctly classied. Other formation variables composing of in-vehical time, excess time and leave home time difference need to be considered for further study.

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