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STRATEGIES ENHANCING WATER TRANSPORTATION USING ECONOMETRIC MODEL APPROACH

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Abstract: The goal of this study is to propose a number of water transportation-related strategies which enhance the usage of the water transportation mode. In this study, Nonthaburi area, which is suburban of Bangkok, and Downtown Bangkok were selected as the study areas for the analysis. In contrast to the surface transportation, water transportation has a potential to provide a good service for passengers and goods movements. Particularly, in Bangkok there is a Chao Phraya river which runs through the center of city. It provides reliable, pollution-free, and scheduled transportation service. To obtain the model representing the trip characteristics and mode choice behavior, the Revealed Preference (RP) is employed. The Multinomial and Nested Logit Model were examined in order to explain the mode choice behaviors of travelers who travel between the study areas. The significant attributes in demand model were identified. Examples of significant attributes are in-vehicle travel time, out-of vehicle travel time, travel cost, number of car ownership, income level. The results showed that different trip purposes, work and non-work trips, had totally different mode choice behaviors. In the application stage, the developed model is employed to estimate the effects of policy decisions on travel behavior of overall patronage by changes in travel time and cost of water transportation mode. Several strategies that can improve the water transportation mode are discussed including service frequencies, information technology and multimodal transit center.

Key Words: Water Transportation, Mode Choice, Logit Model

1. INTRODUCTION

In contrast to the surface transportation, water transportation has a potential to provide a good service for passengers and goods movements. It provides reliable, pollution-free, and scheduled transportation service. The goal of this study is to propose a number of water transportation-related strategies which enhance the usage of the water transportation mode. In this study, Nonthaburi area, which is suburban of Bangkok, and Downtown Bangkok are selected as the study areas for the analysis.

To obtain a model representing the trip characteristics and mode choice behavior, the Revealed Preference (RP) is employed. The Multinomial and Nested Logit Model are examined in order to explain the mode choice behaviors of travelers who travel between the study areas. After identifying significant attributes in mode choice behaviors, this study estimates the effects of policy decisions on travel behavior of overall patronages caused by changes in significant attributes such as travel time and cost of water transportation system.

2. LITERATURE REVIEW

There are several approaches in forecasting the demand of water transportation. The traditional four-step travel demand forecasting process can be employed to predict traffic demand. However, smaller agencies often do not have either the data or the resources to develop and implement complex forecasting models for their systems. Also this approach requires much more data in each step to achieve the objective of study and consequently cause the high budget and time in conducting those data (Savage, 1998). For this reason, a variety of simplified forecasting methods are widely used with socioeconomic data from published sources.

Forecasting water transportation ridership is much more difficult than predicting roadway traffic volumes. The capacity and availability of a ferry depend on the size, frequency, and schedule of the vessels operating on a given day or given portion of a day. The existing studies of the demand analysis of water transportation are broadly classified into two: Time-series analysis and Logit-based demand model.

2.1 Time-Series Analysis Approach

The ability to predict travel demand requires that certain conditions be met. Of this method, first and foremost is that information is available about past travel volumes and characteristics for the types of demand needed to predict, and that the information is accurate and complete. More than any other factor, the quality of the historical data determines the accuracy of the resulting forecasts. A simple straight-line projection, estimated manually using graph paper and a straight edge, made with accurate historical data might be preferable to computer models derived from sparse and unreliable data that produce statistically complex but basically unsound results.

There are two major types of forecasting methods in this category, i.e., time-series analysis (TSA) and explanatory of cause-and-effect models(Savage, 1998). Usually, time-series methods assume that historical patterns observed in ridership data will continue, and that future levels of ridership can be extrapolated from mathematical analysis of past trends. The basic assumption is that the condition growth, economic activity, and ferry services will continue without any significant changes relative to their historical trends.

For explanatory models, they assume that there are definable relationships between ferry demand and one or more independent variables such as population, employment, household income, and retail sales. Statistical methods are applied to various combinations of ferry ridership and independent variables to define these relationships. The least squares regression techniques were applied to combine the ferry ridership and independent variables yielding explanatory or cause-and effect models. These methods are preferred for long-range ferry forecasts because they provide an estimate of the changes in ferry ridership in relation to expected changes in economic activity levels and conditions in the ferry system's service area. Savage (1998) applied these two types of approach to forecast the long-range ridership of ferry in relation to expected changes in economic activity levels and conditions in the ferry system's service area.

Baker and Deardorf (1998) developed the time series analysis models that are used to project ferry ridership at the individual route level by six fare categories. A combination of statistical approaches is used to develop near- to mid-range ridership and revenue forecasting models for Washington State Ferries for use in quarterly budget updates. Regression models with historical and forecast trends in state economic and demographic variables was used to predict system wide ridership by six fare categories for different fare scenarios. The sum of the time series route forecasts is calibrated to the econometric system wide totals to yield unconstrained ridership forecasts by route and fare category.

2.2 Logit-Based Demand Model

Berkowitz (1990) evaluated the viability of implementing new waterborne passenger transportation systems. The analysis of passenger travel characteristics and ridership potential was conducted using a logit-based demand model. The model and data collection techniques included the essential elements of time, cost, comfort, convenience, special enjoyment, and validation. Special emphasis was given to the analysis of passenger travel characteristics and mode choice preference. In addition, the model was used to estimate the effects of policy decisions on travel behaviors. The effects of changes in various policies were represented in terms of overall patronage estimates by varying the values of one or two variables. The competitive modes in his study area consist of passenger ferry, express bus, and automobile.

The mode shift from the Staten Island Ferry to express bus service was attributed to the express buses' improved travel time, levels of comfort and convenience, and pricing structure. He found that the increase in ferry users is attributed to the population explosion on Staten Island, increases in express bus fares, express bus system capacity restraints, and reductions in the general quality of express bus service. In addition, improvements to the express bus system, including special bus lanes and traffic control modifications, have not significantly improved the system's operating characteristics.

Alijarad and Black (1995) analyzed intercity mode choices in the Saudi Arabia-Bahrain corridor using logit model. The study used water transportation, air transportation and land transportation as the main modes available for the commuters. The land transportation mode was further divided into public transit and others. It was found that variables such as frequency of service, immediate decision time, etc. played an important role in the mode choice. As the water transportation service was offered only twice a day, time of decision was considered as one of the major factors in mode choice.

3. STUDY AREA AND DATA COLLECTION

3.1 Water Transportation in Bangkok and Study Area

In Bangkok, demand for transportation facilities and services far outweighs the supply. Although almost of the metropolitan areas face this challenge, the problem is especially acute in Bangkok because of rapid growth in population and employment. Analysis has shown that unless the government takes action to make improvements, transportation system performance will decline dramatically over the next 10 years. In the last decade, traffic engineers and practitioners had come to the conclusion that traffic problems can be mitigated through the appropriate Transportation Demand Management (TDM) measures. TDM is a measure covering a broad range of demand management schemes including a improvement of the public transportation system to encourage the usage of the mass transportation system.

The Chao Phraya river in Bangkok, Thailand, separating the land of Bangkok into two major areas namely "Thonburi" and "Phra Na Khon" zone, is an important mode of transportation not only inside Bangkok but also the boundary of Bangkok. Ferry services on the Chao Phraya River which connect Bangkok with the northern neighboring province of Nonthaburi area are operated in different types of ferry classified by the color of flag as shown in Table 1. The water transportation of Chao Phraya river has played an important role in moving people from suburban to downtown for the last decades. However, the usage of the water transportation of Bangkok has been reported to be decreasing. In this study, two areas in Bangkok which are downtown of Bangkok and Nonthaburi area were selected for data collection and analysis.

TABLE 1. The Ferry Systems Operated along the Chao Phraya River in Bangkok

Operation	Express Ferry (Yellow flag)	Express Ferry (Orange-Red flag)	Normal Ferry (No flag attached)
Origin-Destination	Nonthaburi - Ratburana	Nonthaburi - Wat Rajsingkorn	Nonthaburi - Wat Ratsingkorn
Service Day	Monday to Friday	Monday to Saturday	Daily
Duration	55	50	75
No. of stops	9	18	All (35)
Fare (Baht)	15 (Sathorn) 25 (Rajburana Big C)	10	6-8-10

3.2 Data Collection and Preliminary Analysis

Sample is defined as "a collection of units which has been especially selected to represent a larger population with certain attributes of interest". From the above definition, three aspects have particular importance. First, which population the sample seeks to represent; second, how large the sample should be; and third, what is meant by especially selected (Ortuzar and Willumsen, 1994).

The questionnaire design by applying Revealed Preference(RP) is done prior to distribution to the respondents. The questionnaire has to be clear and ready to respond all necessary variables employed to develop the model. In order to measure how much the respondents experienced to comfort, a set of multiple choices such as very poor, poor, fair, good, and very good was provided to respondents. The respondents had to select only one choice among them to represent their experienced to comfort. The survey was conducted in November 2002 in Nonthaburi and Bangkok's downtown areas and the total number of data used in the model development was 1,060 samples. In this study, in order to measure how much the respondents experienced to comfort, a set of multiple choices such as very poor, poor, fair, good, and very good is provided to respondents. The respondents have to select only one choice among them to represent their experienced to comfort. This choice is then replaced by number from one to five, respectively, and will be used to calibrate the model.

4. METHODOLOGY

The disaggregate demand model has several kinds of model for application. The Logit and Probit models are the two universally applied models in most transportation demand analysis. These two models have different theoretical and mathematical backgrounds in explaining the individual behavior. Nevertheless, in this study, the Logit model was applied because it is less complicated than the Probit model in terms of calculation.

The specific assumptions that lead to the Multinomial Logit Model are (1) the error components are extreme-value (or Gumbel) distributed, (2) the error components are identically and independently distributed (IID) across alternatives, and (3) the error components are identically and independently distributed across observations. Given a set of alternatives C_n, the probability of individual n choosing alternative i from the set of alternatives (P_{in}) is

$$P_{in} = P(U_{in} \geq U_{jn}, \forall_j \in C_n) \tag{1}$$

Substituting the total utility into systematic component and unobservable one of Eq. (1) yields Eq. (2).

$$\begin{aligned} P_{in} &= P(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}, \forall_j \in C_n) \\ &= P(\varepsilon_{jn} - \varepsilon_{in} \geq V_{jn} - V_{in}, \forall_j \in C_n) \end{aligned} \tag{2}$$

As mentioned above, an alternative assumption concerning the distribution of the ε's is IID with Gumbel Distribution Type 1. The final expression of Multinomial Logit Model can be obtained and given by

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{in}}} \tag{3}$$

Within the Logit model, there are two mainly different kinds of Logit model depending on the assumption. The binary or multinomial logit model is an example of logit form. As described above, the assumption of this model defines that the disturbance terms are independent and identically Gumbel distributed (with the scale parameter μ normalized to 1). Another model used in this paper is Nested Logit model that has multidimensional structure of the choice set. The nested logit model, first derived by Ben-Akiva and Lerman(1977), is an extension of the multinomial logit model designed to capture correlations among alternatives. It is based on the partitioning of the choice set C_n into several nests. The basic assumption of nested-logit is that in multidimensional choice set there are some shared unobserved attributes.

5. MODEL ESTIMATION

5.1 Market Segmentation

At first a model was tried with the assumption that there was no taste difference between trip purposes. The value of travel time for different trip purpose was assumed to be the same. Moreover those travelers with different trip purpose were assumed to have the same structure of modal choice. For this, a market segmentation test by trip purpose was done to verify the different taste between work and non-work trip. The assumption was that two trip purpose groups have totally different mode choice behavior and each group has its own utility function that does not relate with the pooled model. The coefficients of segmented model using the same model structure and specification to the best model from the pooled data set were seen to have the same sign except number of car ownership. Table 2 shows different characteristics between work and non-work trips.

TABLE 2. Estimation Results for Market Segmentation by Trip Purpose

Variables	Pooled	Work Trip	Non-Work
Modal Choice			
- Ferry	2.559	4.998	1.864
	(2.698)	(1.809)	(1.793)
- Bus	2.207	2.258	1.944
	(2.831)	(0.984)	(2.291)
- Van	1.68	0.8101	1.61
	(2.000)	(0.339)	(1.740)
- Car	0.9311	-0.763	0.9217
	(1.171)	(-0.347)	(1.034)
Total Travel Cost			
- Ferry	-0.02521	-0.02999	-0.02171
	(-1.868)	(-0.806)	(-1.468)
- Bus	-0.01776	-0.01636	-0.02113
	(-2.364)	(-0.972)	(-2.441)
- Van	-0.01776	-0.01636	-0.02113
	(-2.364)	(-0.972)	(-2.441)
- Car	-0.004404	-0.004582	-0.004894
	(-1.659)	(-0.742)	(-1.620)
- Taxi	-0.004404	-0.004582	-0.004894
	(-1.659)	(-0.742)	(-1.620)
Total Travel Time			
- Ferry	-0.01533	-0.05039	-0.01058
	(-2.474)	(-2.942)	(-1.549)
- Bus	-0.01149	-0.01997	-0.009919
	(-3.934)	(-2.553)	(-3.020)
- Van	-0.152	-0.02243	-0.01372
	(-2.719)	(-1.621)	(-2.198)
- Car	-0.02176	-0.03837	-0.01839
	(-2.859)	(-2.292)	(-2.051)
- Taxi	-0.023	-0.07681	-0.01841
	(-1.817)	(-1.769)	(-1.343)
Access Zone	-0.5343	-0.6269	-0.4808
(Speicific to ferry)	(-2.229)	*(-1.172)*	(-1.761)
No. of Car Ownership	0.242	*-0.3325*	0.2721
(Speicific to car)	(1.998)	*(-1.049)*	(2.069)
Drive-alone (da) or Shared-ride (sr) Dummy	1.398	3.208	1.264
(Speicific to car)	(4.388)	(3.842)	(3.311)
Comfort	0.2907	0.6447	0.2436
	(3.107)	(2.484)	(2.369)
Seat Available	0.8364	0.5132	0.8884
(Specific to ferry and bus)	(3.405)	*(0.896)*	(3.180)
Income	-0.00002185	-0.00005556	-0.000007886
(Specific to bus)	(-1.943)	(-2.183)	*(-0.566)*
No. of Coefficients	18	18	18
L(β)	-542.842	-95.6771	-433.874
L(0)	-754.952	-165.049	-589.903
Rho Square (ρ^2)	0.280958	0.420312	0.264499
Rho Bar Square	0.257116	0.311254	0.233986
-2(L(0) - L(β))	424.22	138.7438	312.058
No. of Data	954	206	748

In order to judge whether the segmented model is better than the pooled model, the total absolute deviation was calculated. The total absolute deviation for the pooled model was obtained by summing the absolute deviation from all modes. For the segmented model, the weighted average deviation of each mode was first carried out. Then the total absolute deviation of segmented model was obtained by summing the weighted average deviation from all modes. The total absolute deviation of pooled and segmented model in this study was found to be 119.78 and 142.90, respectively. Thus, from the perspective of model calibration, the pooled model was considerably better than the segmented model.

5.2 Nested Logit Model and Multinomial Logit Model

Six different types of nested logit model were developed and compared with multinomial logit model. Based on the log-likelihood values of the nest logit model and the results of t-test of each independent variables, multinomial logit model was found to be better than nested logit model.

5.3 Value of Travel Time

Another perspective of the suitability of the model can be examined by evaluating the value of travel time. For the pooled model, the implied value of total travel time was computed using the estimated total journey time and total cost coefficients. For work and non-work trip, the implied value of travel time was computed differently according to the travel time variables used in the model. Table 3 shows the result of value of travel time for pooled, work trip, and non-work trip model, respectively. It was observed that the value of travel time for work trip was higher than that of the pooled model while the non-work trip had the lowest value of travel time. This result was also consistent with the *priori* expectation.

TABLE 3. Implied Value of Time(VOT) for Market Segments

Pooled	Coefficient			VOT	
	List	Time	Cost	(Baht/min.)	(Baht/hr)
Ferry	Total Travel Time	-0.01533	-0.01776	0.86	51.79
Bus	Total Travel Time	-0.01149	-0.01776	0.65	38.82
Van	Total Travel Time	-0.0152	-0.01776	0.86	51.35
Car	Total Travel Time	-0.02176	-0.004404	4.94	296.46
Taxi	Total Travel Time	-0.023	-0.004404	5.22	313.35
Work Trip					
Ferry	IVTT	-0.06613	-0.03386	1.95	117.18
	Waiting time	-0.01545	-0.03386	0.46	27.38
	Walking time	-0.09309	-0.03386	2.75	164.96
Bus	IVTT	-0.01684	-0.02292	0.73	44.08
	OVTT	-0.02743	-0.02292	1.20	71.81
Van	IVTT	-0.01042	-0.02292	0.45	27.28
	OVTT	-0.04914	-0.02292	2.14	128.64
Car	Total Travel Time	-0.03696	-0.006613	5.59	335.34
Taxi	Total Travel Time	-0.03696	-0.004687	7.89	473.14
Non-Work Trip					
Ferry, Bus, Van	IVTT	-0.01009	-0.02145	0.47	28.22
	OVTT	-0.01034	-0.02145	0.48	28.92
Car	Total Travel Time	-0.01838	-0.004864	3.78	226.73
Taxi	Total Travel Time	-0.01845	-0.004864	3.79	227.59

Comparing the result of value of travel time calculated from discrete choice model with other study should be done to roughly check the reasonableness of the developed model. The value of travel time from a previous study is shown in Table 4. The result from the developed model is rather higher than that of the previous study, particularly in case of car and taxi. However, the previous study considered the value of time for all trip purposes (pooled) rather than specific to any trip purpose. It is expected that the value of time for work trip should be higher than that of the non-work trip and pooled model.

In this study, the values of time of ferry, bus, and van for both pooled and segmented model were found to be in the same range as obtained from the previous study. However, the values of travel time of private car and taxi for both the pooled and segmented model were comparatively higher than those of the previous study. The segmented model, however, was selected and will be further applied in this study. It is because the segmented model includes the more detail of travel time variables, and therefore it would be more useful when applied to the policy sensitivity analysis.

TABLE 4. Value of Time (VOT) from Previous Study

VOT	Year 1997	Year 2001
Private Car (Baht/vehicle-hr.)*	131.05	150.07
Public Transportation (Baht/person-hr.)		
- Good condition	74.36	85.70
- Normal condition	33.50	38.60

* UTDM(2001)

6. POLICY SENSITIVITY ANALYSIS AND IMPLICATION

6.1 Elasticity Analysis

Elasticity analysis is a measurement of response in choice probability to changes in attributes of an alternative. Both the direct and cross elasticities were obtained as shown in Table 5 for work and non-work trip. Since the elasticity equations are based on the assumption that the independent variables for which the elasticity are being derived are continuous variables, the selection of variables used to analyze were all levels of service and travel cost variables. It can be said that an attribute has an elastic effect on choice probability when the absolute value of aggregate elasticity is greater than one. The attribute is inelastic when the absolute value of aggregate elasticity is less than one.

The direct elasticity for work trip revealed that in-vehicle travel time of ferry has higher negative influence on the probability of ferry choice. In other words, one percent decrease in in-vehicle travel time of ferry will cause 1.629 and 0.325 percent increase in the probability of ferry choice for work trip and non-work trip, respectively. The cross elasticity of ferry choice revealed that total travel times of car and in-vehicle travel time of bus have higher influence on probability of ferry choice. For non-work trip, in-vehicle travel time of bus and total travel time of car have higher influence on ferry choice.

In this section, the sensitivity analysis of the various policies as an improvement of water transportation was analyzed in order to estimate the ridership of water transportation. For this, incremental logit model was used instead of direct calculation from elasticity.

6.1.1 Reducing Total In-vehicle Travel Time of Ferry

There are several measures that can be applied to reduce total in-vehicle travel time of ferry such as promoting ferry performance, enhancing access and egress modes to water transportation. The sensitivity result of this policy for both work and non-work trip is shown in Table 6.

Results in Table 6 reveal that as the total in-vehicle travel time of ferry decrease every 5 percent, ferry passenger will increase by 1.4 and 0.2 percent for work and non-work trip, respectively. It can be seen that work trip is more sensitive to total in-vehicle travel time than non-work trip. Also every 5 percent decrease in in-vehicle travel time of ferry will cause 0.2 percent decrease in car users for work trip. For non-work trip, the decrease is rather marginal.

TABLE 5. Attributes Elasticity for Work and Non-work Trip

Work	Ferry	Bus	Van	Car	Taxi
Total Walking Time	-0.123	NA	NA	NA	NA
Total Wait Time	-0.119	NA	NA	NA	NA
Total In-vehicle Travel Time	-1.629	0.469	0.162	NA	NA
Total Out-of Vehicle Travel Time	NA	0.231	0.234	NA	NA
Total Travel Time	NA	NA	NA	0.679	0.022
Total Travel Cost	-0.271	0.115	0.205	0.173	0.007
Non-Work					
Total In-vehicle Travel Time	-0.325	0.439	0.078	NA	NA
Total Out-of Vehicle Travel Time	-0.134	0.129	0.031	NA	NA
Total Travel Time	NA	NA	NA	0.412	0.107
Total Travel Cost	-0.232	0.171	0.066	0.141	0.067

TABLE 6. Impact on Modal Split by Reducing Total In-vehicle Travel Time of Ferry

% Decrease in Total $IVTT_{Ferry}$	Ferry (%)	Bus (%)	Van (%)	Private Car (%)	Taxi (%)
0%	16.5	38.8	13.1	30.1	1.5
5%	17.9	38.0	12.9	29.7	1.4
10%	19.3	37.1	12.8	29.4	1.4
15%	20.7	36.3	12.6	29.0	1.4
20%	22.0	35.4	12.5	28.6	1.4
25%	23.4	34.6	12.3	28.2	1.4
30%	24.7	33.8	12.2	27.9	1.4
Non-Work					
0%	11.4	52.3	10.0	23.1	3.2
5%	11.6	52.1	10.0	23.1	3.2
10%	11.7	52.0	10.0	23.1	3.2
15%	11.9	51.9	10.0	23.0	3.2
20%	12.1	51.7	10.0	23.0	3.2
25%	12.3	51.6	10.0	23.0	3.1
30%	12.5	51.4	10.0	23.0	3.1

6.1.2 Reducing Total Travel Cost of Ferry

There are several measures to reduce total travel cost of ferry such as adjusting fare structure of ferry, introducing free of charge feeder buses for monthly ticket. The result of this sensitivity is shown in Table 7 for work trip and non-work trip, respectively. Results in Table 7 reveal that as the total travel cost of ferry decreases every 5 percent, ferry passenger will increase by 0.2 and 0.1 percent for work and non-work trip, respectively. For every 5 percent decrease in total travel cost of ferry, bus riders will decrease by 0.1 percent for both trips.

TABLE 7. Impact on Modal Split by Reducing Total Travel Cost of Ferry for Work Trip

% Decrease in Total Travel $Cost_{Ferry}$	Ferry(%)	Bus(%)	Van(%)	Private Car(%)	Taxi(%)

0%	16.5	38.8	13.1	30.1	1.5
5%	16.7	38.1	13.1	30.0	1.5
10%	17.0	38.6	13.0	30.0	1.5
15%	17.2	38.4	13.0	29.9	1.5
20%	17.4	38.3	13.0	29.8	1.4
25%	17.6	38.2	13.0	29.8	1.4
30%	17.9	38.1	12.9	29.7	1.4
% Decrease in Total Travel Cost$_{Ferry}$ (Non-work trip)					
0%	11.4	52.3	10.0	23.1	3.2
5%	11.5	52.2	10.0	23.1	3.2
10%	11.6	52.1	10.0	23.1	3.2
15%	11.8	52.0	10.0	23.1	3.2
20%	11.9	51.9	10.0	23.0	3.2
25%	12.0	51.8	10.0	23.0	3.2
30%	12.2	51.7	10.0	23.0	3.2

6.1.3 Reducing Total Walking Time of Ferry

Sensitivity result of reducing total walking time of ferry for work trip is presented in Table 8 reveals that for work trip, every 5 percent decrease of total walking time of ferry, ferry ridership will increase by 0.1 percent. There are several ways to reduce total walking time of ferry such as providing feeder buses, enhancing access and egress modes, etc.

6.1.4 Reducing Total Waiting Time for Ferry

Sensitivity result of reducing total waiting time of ferry for work trip is presented in Table 8. There are several measures to reduce total waiting time of ferry such as increasing operating frequency of ferry, enhancing access and egress modes to water transportation, etc. Result reveals that for work trip, every 5 percent decrease in total waiting time of ferry, the ferry ridership will increase by 0.1 percent.

6.1.5 Reducing Total Out-of-vehicle Travel Time of Ferry

Sensitivity result of reducing total out-of-vehicle travel time for non-work trip of ferry is shown in Table 8. There are several measures to reduce total out-of-vehicle travel time such as providing new feeder services, increasing frequency of present access and egress modes, etc. It reveals that for non-work trip, every 5 percent decrease in total out-of-vehicle travel time will result in 0.1 percent increase in ferry ridership.

6.2 Implication of Sensitivity Analysis

In previous section, new market share resulting from improvement of level of service of water transportation was explored. Based on them, effective policies for gaining more water transportation riders are suggested separately for work trip and non-work trip as follows:

TABLE 8. Impact on Modal Split by Policy Type

% Decrease in Total Walking TImet$_{Ferry}$	Ferry (%)	Bus(%)	Van(%)	Private Car(%)	Taxi(%)

0%	16.5	38.8	13.1	30.1	1.5
5%	16.6	38.8	13.1	30.1	1.5
10%	16.7	38.7	13.1	30.1	1.5
15%	16.8	38.6	13.1	30.0	1.5
20%	16.9	38.5	13.1	30.0	1.5
25%	17.0	38.4	13.1	30.0	1.5
30%	17.1	38.4	13.1	30.0	1.4
% Decrease in Total Waiting Time$_{Ferry}$ (Work Trip)					
0%	16.5	38.8	13.1	30.1	1.5
5%	16.6	38.8	13.1	30.1	1.5
10%	16.7	38.7	13.1	30.0	1.5
15%	16.8	38.6	13.1	30.0	1.5
20%	16.9	38.6	13.1	30.0	1.5
25%	17.0	38.5	13.1	30.0	1.5
30%	17.1	38.5	13.1	29.9	1.5
% Decrease in Total OVTT$_{Ferry}$ (Non-Work Trip)					
0%	11.4	52.3	10.0	23.1	3.2
5%	11.4	52.2	10.0	23.1	3.2
10%	11.5	52.2	10.0	23.1	3.2
15%	11.6	52.1	10.0	23.1	3.2
20%	11.7	52.0	10.0	23.1	3.2
25%	11.8	52.0	10.0	23.1	3.2
30%	11.8	51.9	10.0	23.1	3.2

6.2.1 Work Trip

In terms of travel time, the results revealed that the commuters were more sensitive in in-vehicle travel time than out-of-vehicle travel time. For this, water transportation services such as enhancing operating speed and adjusting skip stop strategy should be adopted. Regarding, total travel cost, the results of the sensitivity analysis revealed that total travel cost has significant influence on ferry user. Commuters were less sensitive to total travel cost than total travel time. Adjusting fare structure, providing free feeder buses can be adopted in this case. However, financial viability has to be taken into consideration.

For work-trip, males preferred to use private car than other public transportation modes, while females preferred to use bus. Younger commuters preferred to use bus, public van, ride sharing, and ferry more than elder people, while the elder people preferred to use private car as driving alone more than younger people. Higher income people preferred to use cars for their work trips while the lower income people preferred to use bus. The income level seems did not have any systematic impact on modal choice of other modes. Students and daily labor preferred to use bus than other modes while the business owner preferred to use drive alone than other modes. Car ownership was a strong index for the probability of choosing private car (for both drive alone and ride sharing) as a commuting mode. The number of family members did not have any systematic relationship with modal choice.

Travel cost, travel time, and convenience played a significant role in modal choice than the other reasons. Ferry users cared much about travel time while bus users cared much about travel cost. The van, drive alone, ride sharing, and taxi mainly cared about the convenience.

6.2.2 Non-work Trip

In terms of travel time, non-work trip makers were more sensitive to total in-vehicle travel time than total out-of-vehicle travel time. In this case, policies such as increasing frequency of ferrys, enhancing access and egress modes should be applied. Regarding total travel cost, non-work trip commuters were less sensitive to total travel cost than total in-vehicle travel time. Restructuring ferry fare structure, providing free access/egress modes are recommended in this context. Overall results revealed that commuters are more sensitive to total in-vehicle travel time of ferry than other time components and total travel cost. So measures proposed above should be applied to increase the usage of water transportation system.

The travel behavior pattern was analyzed based on the socio-economic characteristics of respondents and the trips characteristics. Both males and females preferred to use bus than other modes. The percentage of using bus did not have any systematic relationship with age of travelers while for other modes the results were similar to that in work-trip. Higher income people preferred to use cars while the lower income preferred to use bus. Number of car ownership in household was a good indicator of car usage. As the number of household member increased the usage of ride sharing increased as well. Ferry users cared more about travel time while bus users cared about travel cost. The users of van, drive alone, ride sharing, and taxi mainly cared about the convenience. The results of Market Segmentation test revealed that different trip purposes, work and non-work trips, had totally different mode choice behavior. Value of travel time of work trip was higher than that of the non-work trip.

7. CONCLUDING REMARKS

Bangkok has a good potential to rely on water transportation in order to improve the performance of the overall transportation system. It is because Bangkok has Chao Phraya river which runs through the center of city, and water transportation provides reliable, environment friendly, and scheduled transportation service. However, it is known that patronage of water transportation using Chao Phraya river has been decreasing. In this context, by developing logit model, this study proposed a number of water transportation-related strategies which enhances the usage of the water transportation mode. Nonthaburi area, which is suburban of Bangkok, and Downtown Bangkok were selected as the study areas for the analysis. To develop a logit model representing the trip characteristics and mode choice behavior, the revealed preference based survey was employed. The Multinomial and Nested Logit Model were examined in order to explain the mode choice behaviors of travelers who travel between the study areas. The results showed that different trip purposes, work and non-work trips, had totally different mode choice behaviors.

In the application stage, the developed model is employed to estimate the effects of policy decisions on travel behavior of overall patronage by changes in service characteristics of water transportation mode. Based on the sensitivity analysis, following strategies are suggested:

- In terms of gaining more ferry riders of work trip, the performance of ferry service such as operating speed and adjusting skip stop strategy should be enhanced to reduce in-vehicle travel time of ferry. Adjusting fare structure and/or providing free feeder buses can be adopted in this case. To gain more ferry riders of the non-work trip, since the non-work trip makers were more sensitive in in-vehicle travel time than out-of-vehicle travel time, the same policy as of work trip should be adopted
- Another issue that reflects the inconvenience of using ferry is the long walking distance on access and/or egress to/from pier. The existing condition at the

Nonthaburi pier is a very good example for this case. It is because most of the bus coming from Ngam Wong Wan did not provide the services up to Nonthaburi pier. If the travelers want to go to Nonthaburi pier, they have to change the bus or further walk to Nonthaburi pier. The coordination with bus agency should be taking into consideration.

- The lack of ferry services information is another issue that can be solved. The information such as the nearest get-in and get-off pier for various places, and other public transportation that link to each pier should be provided to travelers.

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