■ 論 文 ■

Modal Choice with Travel Time Reliability

통행시간 신뢰도를 고려한 통행수단선택모형에 관한 연구

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Key Words : Travel Time Reliability, Standard Deviation of Travel Time, Maximum Delay of Travel Time, Discrete Choice Model

요 약

통행수단선택에 있어 여행자들은 여행수단의 통행시간 뿐만 아니라 해당 수단의 신뢰도를 함께 고려하게된다. 본 논문에서는 통행시간의 신뢰도는 삼각분포를 기반으로 하는 통행시간의 표준편차(Standard Deviation)와 최대지체시간(Maximum Delay)으로 정의하여 모형을 개발하였다. 모형의 개발을 위해 Multinomial Logit(MNL)과 Nested Logit 모형이 구축되어 상대적으로 우수한 MNL을 이용한 모형의 결과 통행수단의 신뢰도는 중요한 요소임을 보였다.

모형의 개발을 위해 통행시간의 표준편차와 최대지체시간의 변수를 사용하여 모형을 개발하였으며 최종적으로 최대지체시간이 보다 적절한 변수임을 보였다. 또한, 본 논문에서는 통행시간의 신뢰도가 확보되는 수상교통수단을 중심으로 서비스 수준의 향상에 관계되는 정책의 효과를 분석하기 위하여 개발된 모형의 민감도 분석이 이루어 졌으며, 이는 정책결정자와 교통계획가들로 하여금 대안선택의 분석에 유용한 도구로 쓰일 수 있다. 민감도 분석을 바탕으로 수상교통을 중심으로 통행시간의 신뢰도가 확보되는 수단의 서비스 향상을 위한 정책들을 제시하였다.

1. Introduction

Surface transportation in urban areas, in general, experiences a problem of low travel time reliability. Non-recurring traffic congestion is one of the prime factors affecting the travel time reliability in case of surface transportation. In mode choice behavior, travelers consider not only expected travel time but also travel time reliability. Therefore, in order to understand the mode choice behaviors, it is necessary to understand the value of travel time reliability.

Information of cost and reliability of transportation modes are necessary to make policies and estimate the benefits that are gained from improving reliability or shifting the users to more reliable transportation mode. However, it is not easy to measure the travel time reliability and to select the most appropriate measurement. In order to identify its importance and estimate the value of reliability, the modal choice analysis is applied to understand the relationship between modal choice behavior and travel time reliability.

Bangkok is selected for the study because Chao Phraya River runs through the center of the city and different types of water transportation are served. Particularly, Nonthaburi area, which is suburban of Bangkok, and Downtown Bangkok were selected as the study areas for the analysis. In this area surface transportation modes are available and easy to access but its reliability is not good due to heavy congestion problem. In contrast, water transportation is reliable mode but has low accessibility.

This research attempts to investigate the importance of travel time reliability and to estimate the value of travel time reliability of transportation users in order to assess the benefits gained from improving the reliability

2. Literature Review

Travel time reliability is a measure of the expected range in travel time and providesquantitative measure of the predictability of travel time. Many researchers defined reliability in different meanings depended on their objectives or purposes. Polus and Schofer(1976) defined reliability as the operational consistency of a facility over an extended period of time.Tayler(1982) stated that reliability has several components including the probability that the service will operate, adherence to timetables and scheduled frequencies, and the ability to reach a destination by nominated time. Wigan et al. (2000) defined reliability as the portion of the designated delivery that was late. Bates et al. (2001) defined travel time reliability as a potentially critical influence on any mode or route choice. Definition by HDR(2002) is travel time reliability is the absence of delay not predicted by the Travel Delay Methodology. A measure of reliability must relate to amount of delay not predicted by Travel Delay Methodology or other models performance based on congestion and capacity. Cambridge Systematics(2002) defined the travel time reliability as a measure of the expected range in travel time and provided quantitative measure of the predictability of travel time.

Prashker(1979) classified reliability of transportation mode into six groups: performance, weather, mechanical, travel time, waiting time and parking time reliability. Chen et al.(2000) classified measures of reliability for a road network into three types: connectivity reliability, travel time reliability, and capacity reliability.

Prashker(1979a) studied the characteristics of reliability of transportation modes in urban area by using reliability index. In his research, he used scaling method to identify reliability index. The importance-dimension was used toidentify reliability index that was scaled from zero to one. If reliability equaled to one, it meant that the attribute was extremely importance. Jackson and Jucker(1982) measured travel time reliability and assessed its importance in travel choice. In their study, they selected the mean and variance measures proposed because they had two advantages, theoretical and practical, over other measures. A mean-variance model of travel choice was used to estimate an individual's trade-off between time and variability and so called the "risk aversion coefficient". Traveler whose this coefficient has reached the upper bound consistently chose the more reliable route over the route with possible delays, even when the more reliable route had a longer time than the uncertain route when the delay occurred.

Chen et al.(2000) expressed that travel time reliability was related to capacity reliability which was depended on the demand level of network. They measured capacity reliability as a function of level-of-service. From reliability of capacity, they could simulate travel time reliability by using Monte Carlo Simulation.

Lo and Tung(2000) used a chance constrained network capacity model to analyze road network reliability. Chen and Recker(2000) stated that travel time reliability of road network was caused by demand and supply variation, which were depended on geographic location, time of day, and occurrence of special event. They predicted two types of travel time reliability: path travel time reliability and OD travel time reliability by using the risk taking behaviors. Travel time was a function of volume-to-capacity ratio following Bureau of Public Road(BPR) equation. They used risk-taking behavior and Monte Carlo Simulation estimate volume or demand variability.

In order to estimate value of travel time reliability, there were several methods from the previous studies such as utility method, regression method, direct collection, etc. The basic concept began from the estimation of value of time and was developed to value of reliability or variability. In a discrete choice model, the value of time can be determined from trade-off between coefficients of travel time and travel cost.

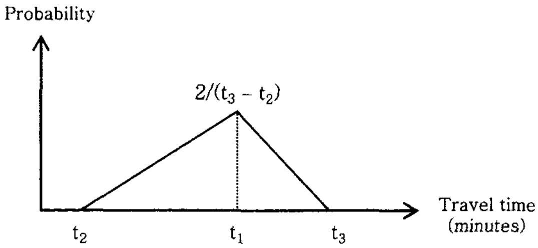
Senna(1994) investigated the value of travel time variability based on the expected utility approach and mean-standard deviation approach, and so called "Senna's model". The arrival time constraint and trip purpose were considered and classified into four different categories: commuters with fixed arrival time, commuters with flexible arrival time, non-commuter with fixed arrival time, and non-commuter with flexible arrival time. This value was used to find the benefits from travel time saving related to the travel time variability.

3. Methodology

1) Sampling Strategy and Survey Design

Sampling strategy for discrete choice analysis infers the vector of parameters of the choice model, or the distribution of the characteristics of the population(Ben-Akiva and Lerman, 2000). Travelers are interviewed to determine their chosen mode and their alternative attributes in order to estimate model parameters. In order to obtain the trip characteristics, traveler characteristics, and traveler behavior including their mode choice, questionnaire is designed to ask individual to provide the actual information about situations they face, or so called "revealed preference". It is divided into three parts: OD pair, traveler characteristics including trip purpose and mode choice selection, and trip characteristics. Since the objective of this study is to investigate the value of travel time reliability, travel time reliability or variability is surveyed about not only main-haul travel time but also egress and access travel time including waiting time for each terminal.

In reality, travelers perceive travel time in term of mode more than mean because they estimate the expected travel time from situations that they often meet. Therefore, the questionnaire is designed to determine the maximum(t3),



〈Figure 1〉 Triangular Distribution of Travel Time

minimum(t2), and mode(t1)of travel time of available transportation modes that are available to travelers. For this, the triangular distribution is used as shown in Figure 1. The mean, variance, and standard deviation of this distribution is derived as follows and shown in following equation (Hesse, 2000).

$$\nu(t) = \frac{(t_1^2 + t_2^2 + t_3^2 - t_1t_2 - t_1t_3 - t_2t_3)}{18}$$

$$SD(t) = \sqrt{\nu(t)}$$

where

$\nu(t)$: variance of travel time

$SD(t)$: standard deviation of travel time

2) Discrete Choice Model

Logit model is based on the utility choice theory. Decision makers will select choice with highest utility. The utility function is composed of two components: the systematic, the observable attribute which is deterministic; and disturbances, the errors from many sources such as imperfect information, and measurement error, omission of important modal attributes, and omission of the characteristics of the individual that affect to choice decision. Usually, the systematic components of utility function are restricted to the class of linear-in-parameters functions. The assumption of logit model is all disturbances are independently and identically distributed(IID), and Gumble-distributed

Mode choice model is useful to estimate demand for each mode and to test sensitivity when policies are applied. The reliability of travel time is linked to multinomial or nested logit model as one variable in utility function of all competitive modes. Reliability variable in utility function is treated as absolute value of standard deviation of travel time or maximum delay. Thus, the travel time reliability is substituted by the standard deviation of travel time or maximum delay in the utility function of logit model.

$$U_i = \beta_0 + \beta_1 T_i + \beta_2 SD_i(or\ D_i) + \beta_3 C_i$$

$$VOTTSD_i = \frac{\beta_2}{\beta_3}$$

where

VOTTSD*i* or VOD*i* : value of travel time standard deviation or maximum delay of mode i (Baht per one-minute delay)

SD_i : absolute value of standard deviation of mode *i*

D_i : Maximum Delay of mode *i*

T_i : travel time of mode *i*

C_i : travel cost of mode *i*

Each model structure from MNL and NL model is developed in order to propose the best specification of model. Generally, three things are considered to develop models. They are formal theories(or informal judgments), goodness-of-fit, and statistical significant test(Ben-Akiva and Lerman, 2000). Many specifications of model, or many types and independent variables of utility function are tried until the model satisfies these standards.

4. Data Collected

1) Standard Deviation

Standard deviation of travel time can be used to measure the reliability. Its absolute value is inversely proportional with reliability. The comparisons of average standard deviation of

<Table 1> Average Standard Deviation (minutes)

Average Standard Deviation		Mode				
		Boat	Bus	Van	Car	Taxi
Access Mode	Waiting Time	2.77	1.76	2.33	-	1.71
	In-Vehicle Travel Time	2.94	1.49	2.13	-	1.47
	Total Time	4.62	1.60	2.73	-	1.20
Main Mode	Waiting Time	2.94	4.96	3.30	-	2.17
	In-Vehicle Travel Time	3.98	10.19	5.28	6.70	6.26
	Parking Time	-	-	-	2.46	-
	Total Time	6.73	14.97	8.33	8.40	8.14
Egress Mode	Waiting Time	2.43	1.46	2.07	-	-
	In-Vehicle Travel Time	3.13	1.54	2.46	-	-
	Total Time	2.91	1.22	2.28	-	-
Total	Total Time	13.27	16.11	11.94	8.42	8.36

<Table 2> Average Maximum Delay

Average Maximum Delay		Mode				
		Boat	Bus	Van	Car	Taxi
Access Mode	Waiting Time	7.41	4.32	6.29	-	3.94
	In-Vehicle Travel Time	8.86	3.27	5.60	-	3.54
	Total Time	13.14	2.58	6.60	-	0.89
Main Mode	Waiting Time	7.26	13.98	8.52	-	5.59
	In-Vehicle Travel Time	11.05	30.70	15.18	20.93	19.58
	Parking Time	-	-	-	6.40	-
	Total Time	18.24	44.64	23.43	25.76	24.82
Egress Mode	Waiting Time	6.12	3.00	5.11	-	-
	In-Vehicle Travel Time	9.71	3.35	6.76	-	-
	Total Time	6.89	0.95	4.62	-	-
Total	Total Time	37.92	47.86	33.95	25.85	25.45

in-vehicle travel time, waiting time and total time of access mode, main mode, and egress mode between Nonthaburi area and downtown of Bangkok were shown in Table 1. It may be seen that among all modes boat has the highest variability in terms of waiting time, in-vehicle travel time, and total time of access and egress mode, but it has the lowest variability in terms of in-vehicle travel time and total time of main mode. It implied that the water transportation mode is more reliable than the land transportation mode in term of in-vehicle travel time of the main mode, but the access and egress mode of water mode is not. This is reasonable because water transportation mode does not face the traffic congestion, while poor accessibility leads to the high variability of travel time of access and egress mode. In contrast to boat mode, bus has the highest reliability of access and egress time among public mode because the access and egress mode of bus is usually walking, but it has the lowest reliability of main mode among all modes. It may be seen that among all modes the standard deviation of boat is not the lowest. This is because the reliability is affected by access and egress mode.

2) Maximum Delay

The maximum delay of travel time can be a good indicator for the reliability of transportation system. Based on the triangular distribution of travel time, the maximum delay is calculated as the difference between maximum and usual travel time(t_3 - t_1).

The comparison of average maximum delay of in-vehicle travel time, waiting time and total time of were shown in Table 2. Water transportation mode has the highest possibility of delay in access and egress among all modes, but the in-vehicle travel time of main mode has the lowest average maximum delay. It implied that the boat has high reliability for journey but the access and egress mode is not reliable in terms of waiting and in-vehicle travel time. Moreover, bus has the highest risk of arriving late among all main modes, while its access and egress mode has the lowest delay among public modes. It implied that bus is the best choice of public transportation user under the consideration of the reliability in access and egress, but it was the worst choice when transportation users consider the reliability of travel time. In addition, bus has the biggest average maximum delay among all modes in term of total time and boat is not the best choice for traveler considering the delay because its reliability was affected by access and egress mode.

5. Model Development

Multinomial and Nested Logit model structures were developed in order to obtain the best model representing trip behavior without travel time reliability. For the Nested Logit model, twelve types of nested structure were applied andmost of the different types of model had the unacceptable logsum parameter value. The acceptable logsum variable has to lie between 0 and 1. If the logsum parameter is greater than 1, the model will collapse to MNL model. Selecting preferred MNL model among the possible models could be done by using various tools such as the likelihood ratio test, the comparison between the values of $\bar{\rho}^2$, the reasonableness of value of time, and the consideration on application of the model.

1) Model with standard deviation

In this study the travel time reliability is expressed in terms of standard deviation and maximum delay. First, a model with SD was developed through the rigorous statistical test and goodness-of-fit measures. The standard deviation of in-vehicle travel time of main mode was added in the utility function for all modes. For the risk-taking driver's, the dummy variable associated with the SD variable was introduced in the utility function as shown in the following equation:

$$U_{in} = \alpha + \beta_k X_{kn} + \delta(SD_{in} R_n)$$

where

U_{in} : utility of mode i for individual n

α : alternative specific constant

β_k : coefficients of attribute k

X_k : attribute k for individual n

δ : coefficient of standard deviation of in-vehicle travel time of main mode

SD_{in} : standard deviation of in-vehicle travel time of main mode i of individual n

R_n : dummy variable for risk-taking behavior of individual n

: 0, if $SD_1 \geq SD_2$ and $TT_1 \geq TT_2$

: 1, otherwise

TT_1 : In-vehicle travel time of main mode for chosen mode

TT_2 : In-vehicle travel time of main mode for not chosen mode

SD_1 : SD of chosen mode

SD_2 : SD of not chosen mode

The best model with SD is presented in Table 3. For water transportation mode, the value of travel time standard deviation (VOTTSD) was very low when compared with land transportation mode. It implied that shifting the surface transportation users to water transportation mode would save a lot of cost of variability when the

〈Table 3〉 MNL Model with Standard Deviation

Variable	Estimated Coefficients	t-statistic
Constant		
- Boat	2.629	2.318
- Bus	4.158	4.237
- Van	2.651	2.463
- Car	0.943	1.047
No. of Car Ownership (specific to car)	0.3851	2.527
Drive Alone or Shared Ride (dummy)	1.398	3.659
Total Time		
- Boat	-0.02573	-2.879
- Bus	-0.00577	-1.075
- Van	-0.0212	-2.763
- Car	-0.01691	-1.767
- Taxi	-0.01515	-1.046
Total Cost		
- Boat	-0.02093	-1.182
- Bus, Van	-0.02014	-1.997
- Car, Taxi	-0.00571	-1.775
SD of In-Vehicle Travel Time of Main Mode		
- Boat	-0.04029	-0.556
- Bus	-0.6878	-12.98
- Van	-0.2504	-4.151
- Car	-0.1762	-3.884
- Taxi	-0.1874	-2.69
Restricted Log-likelihood	-754.952	
Log-likelihood at Convergence	-303.343	
ρ^2	0.598	
$\bar{\rho}^2$	0.573	
-2(L(0) - L(β))	903.218	

〈Table 4〉 Value of Time and Value of travel time Standard Deviation

Mode	VOT		VOTTSD
	(Baht/min.)	(Baht/hr)	(Baht/min.)
Boat	1.23	73.76	1.92
Bus	0.29	17.18	34.15
Van	1.05	63.16	12.43
Car	2.96	177.69	30.86
Taxi	2.65	159.19	32.82

SD was equal for all modes.

For van, car, and taxi, the coefficients of SD were not different so the mode with higher travel cost will suffer the variability. Since this model calibrated by using the dummy variable for risk-taking behavior or the variability will not affect to risk prone group, the VOTTSD was highest for bus because this mode has the highest SD among all. However, the absolute values of VOTTSD for land transportation were very high compared with the value of travel time. In this sense, it is considered that the model with SD is not appropriate for estimating value of variability.

2) Model with Maximum Delay

From the model with standard deviation variable, it gave the value of VOTTSD very high because the absolute value of SD was very low. As a result, the maximum delay variable was applied to the logit model. Eight different models were tested and selected the best model which is shown in Table 5.

Comparing the value of travel time with previous study and the satisfied value of delay were the major criteria in the model selection. The sign of Car ownership coefficient was reasonable because when the number of car in household increases then travelers prefer use car to the other mode. Drive-alone or shared-ride dummy variable was significant and its sign was reasonable. Effect of Delay of in-vehicle travel time variable was highest for bus, while lowest for boat because bus has the longest delay, while

〈Table 5〉 MNL Model with Maximum Delay

Variable	Estimated Coefficients	t-statistic
Constant		
- Boat	2.317	1.962
- Bus	3.587	3.66
- Van	1.952	1.663
- Car	1.002	0.9838
No. of Car Ownership (specific to car)	0.4145	2.893
Drive Alone or Shared Ride (dummy, specific to car)	1.715	4.351
Total Time		
- Boat	-0.02109	-2.465
- Bus	-0.00847	-1.985
- Van	-0.0194	-2.712
- Car	-0.01804	-1.997
- Taxi	-0.01862	-1.253
Total Cost		
- Boat	-0.0259	
- Bus	-0.0276	
- Van	-0.01055	
- Car	-0.00677	
- Taxi	-0.0036	
Delay of In-vehicle Travel Time of Main Mode		
- Boat	-0.04935	-1.949
- Bus	-0.2181	-12.1
- Van	-0.1058	-4.692
- Car	-0.09562	-5.916
- Taxi	-0.1009	-4.529
Restricted Log-likelihood	-754.952	
Log-likelihood at Convergence	-344.915	
ρ^2	0.543	
$\bar{\rho}^2$	0.515	
-2(L(0) - L(β))	820.074	

〈Table 6〉 Value of Travel Time and Value of Delay of MNL Model with Maximum Delay

Mode	VoT		VoD
	(Baht/min.)	(Baht/hr)	(Baht/min.)
Boat	0.81	48.86	1.91
Bus	0.31	18.40	7.90
Van	1.84	110.33	10.03
Car	2.66	159.79	14.12
Taxi	5.17	309.99	28.00

〈Table 7〉 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

Source: UTDM(2001)

boat was lowest. It implied that when service improvement of all modes is equal, travelers are attracted to boat more than other modes, or travelers with risk-averse behavior prefer to use boat than the other mode and would not like to use bus mode.

When comparing the results of value of time (VoT) with previous study in year 2001, boat, car, and taxi were reasonable, while bus and van were not good. For taxi, although its value was very high, it was still acceptable because taxi mode is usually used in the rush hour with the highest cost among all modes. For bus, VoT (18.40 Baht/hr.) was less than the previous research (38.60 Baht/hr); however, it is in acceptable range. For VoT of van (110.33 Baht/hr.), it is higher than that of the previous study (85.70 Baht/hr); however, its value can still be accepted if van is assumed that it is public transportation mode with good condition. It is assumed that some VoT of this study was different from previous research because the sizes of sampling, interviewers and the OD pairs or survey place were different.

Although no previous study estimates the value of delay (VoD) in Thailand, the value was still satisfied especially in land transportation mode. For water transportation mode, the value was very low when compared with land transportation mode. Among land transportation modes, bus has the highest average of maximum delay, which is similar to in-vehicle travel time.

3) Comparisons Between Models with and without Reliability

The comparisons between model with and without reliability by using the log-likelihood ratio, γ^2, and $\overline{\rho}^2$ indicated that the model with reliability was better than without reliability because these values of the model with reliability were much higher than that of the model without reliability. Moreover, the likelihood ratio test between these two models was performed and the result implied that both models were significantly different. In this sense, the model with higher likelihood ratio was selected as the best model.

From the t-statistic of coefficients of standard deviation and maximum delay, they were accepted at 5% level of significance, thus it can be concluded that travel time standard deviation and maximum delay are important factor in mode-choice decision. In addition, the VoT of model with delay was much more reasonable than the one without delay when comparing with previous research especially the VoT of car and taxi. Consequently, it could be concluded that model with reliability was better than without reliability.

6. Policy Sensitivity Analysis

From the analysis of direct and cross aggregate elasticities of each mode, the policies for enhancing the water transportation users can be suggested. As mentioned in part of elasticity analysis, improving level-of-service of water transportation mode, and increasing total travel cost of land transportation modes are possible policies for enhancing water transportation mode. There are three attributes affecting the mode-choice decision: total travel time, total travel cost, and delay of boat. The analysis result of policy sensitivity of boat mode corresponding to the improvement of total travel time is shown in Table 8.

The result revealed that as the total travel time of boat decreases every 5%, water transportation users will be increased as much as 2.44 percent, while bus, van, car, and taxi users will be decreased0.30, 0.38, 0.37, and 0.91 percent, respectively. The proportions of travelers shifting from bus, van, car, and taxi to boat mode were 48.36, 13.20, 29.98, and 8.46 percent, respectively. Therefore, improving the total travel

〈Table 8〉 Impact on Modal Split by Reducing Total Travel Time of Boat

% Decrease Total Time of Boat		Modal Split					% Change				
		Boat	Bus	Van	Car	Taxi	Boat	Bus	Van	Car	Taxi
0%	No. of Trips	119	471	102	235	27	-	-	-	-	-
	(%)	(12.47)	(49.37)	(10.69)	(24.63)	(2.83)					
5%	No. of Trips	122	470	102	234	27	2.44	-0.30	-0.38	-0.37	-0.91
	(%)	(12.78)	(49.22)	(10.65)	(24.54)	(2.80)					
10%	No. of Trips	125	468	101	233	27	4.88	-0.60	-0.75	-0.74	-1.82
	(%)	(13.08)	(49.08)	(10.61)	(24.45)	(2.78)					
15%	No. of Trips	128	467	101	232	26	7.33	-0.90	-1.13	-1.11	-2.73
	(%)	(13.39)	(48.93)	(10.57)	(24.36)	(2.75)					
20%	No. of Trips	131	465	100	232	26	9.77	-1.19	-1.50	-1.48	-3.64
	(%)	(13.69)	(48.78)	(10.53)	(24.27)	(2.73)					

time of boat will attract more from bus users followed by car, van and taxi. There are several policies that can be applied for reducing the total travel time of boat because a trip composes of many components such as walking time, waiting time for access, main, or egress mode, and in-vehicle travel time of access, main, and egress mode. From the trip components, the possible policies are decreasing walking, waiting and in-vehicle travel time. Moreover, the accessibility of water transportation mode is the main problem because waiting time and in-vehicle travel time of both access and egress modes were the highest among all modes. As a result, the policy should focus on the improvement of the accessibility of the access and egress modes rather than the main mode.

7. Conclusions

According to comparison results between model with and without reliability, model with reliability performs better than that without reliability for all tests. The MNL model was developed and total travel cost, car ownership, drive-alone or shared-ride, and reliability were found to be the important factors affecting the mode choice decision. Reliability played an important role in mode choice decision for travelers considering the maximum delay of in-vehicle travel time of main mode. Transportation users considered out-of-pocket cost in terms of fare or fuel more than in-pocket cost (such as maintenance cost of car), so the value of travel time and delay for taxi users was higher than that of car users. In addition, car users consisted of drive-alone and shared-ride so their value of time and delay was much less than taxi users.

Since values of reliability were higher than values of time, the policy to increase travel time reliability gained more benefit than to reduce the travel time at the same level of improvement. The best alternatives for reducing the user or social costs should be the policy that shifts less reliable transportation users to more reliable mode. The government can enhance the transportation system by making the policy from elasticities analysis of attributes such as cost, mean and variance of access/egress time, waiting time, and main-haul travel time.

References

1. Bates, J., et al. (2001), "The valuation of reliability for personal travel", Transportation Research Part E 37, pp.191~229.
2. Ben-Akiva, M., and Lerman, S.R.(1985), Discrete Choice Analysis: Theory and Application to Travel Demand, Massachusetts Institute of Technology, Cambridge, Mass.

3. Cambridge Systematics, Inc., "7.0 Benefit/Cost Analysis", Twin Cities Ramp Meter Evaluation Final Report.
4. Chen, A., et al. (2000), "Effect of Route Choice Models on Estimating Network Capacity Reliability", Transportation Research Record 1733, pp.63~70.
5. Chen, A., and Recker, W.W.(2000), "Considering Risk Taking Behavior in Travel Time Reliability", UCI-ITS-WP-00-24
6. Hesse, R.(2000), "Triangle Distribution: Mathematica Linked for Excel,"Decision Line, pp.12~14.
7. HDR Engineering, Inc., "Technical Memorandum No. 2: Travel Time Reliability", Cross Cascades Corridor Analysis Project, pp.1~5
8. Jackson, W.B., and Jucker, J.V. (1981), "An Empirical Study of Travel Time Variability and Travel Choice Behavior", Transportation Science 16, pp.460~475.
9. Lo, H.K., and Tung, Y.K. (2000), "Chapter 11: A Chance Constrained Network Capacity Model", Reliability of Transport Networks, pp.159~172.
10. Prashker, J.N.(1979a), "Direct Analysis of The Perceived Importance of Attributes of Reliability of Travel Modes in Urban Travel", Transportation 8, pp.329~346.
11. Pranshker, J.N. (1979b), "Mode Choice Models with Perceived Reliability Measures", Transportation Engineering Journal, pp.251~262.
12. Taylor, M.A.P. (1982), "Travel Time Variability The Case of Two Public Modes", Transportation Science 16, pp.507~521.
13. UTDM (1998), Urban Transport Database and Model Development Project, Office of the Commission for the Management of Land Traffic, Bangkok, Thailand.
14. Polus, A., and Schofer, J.L. (1976), "Analytic Study of Freeway Reliability", Transportation Engineering Journal, pp.857~870.
15. Senna, L.A.D.S. (1994), "The Influence of Travel Time Variability on The Value of Time", Transportation 21, pp. 203-228.
16. Wigan, M., et al. (2000), "Valuing Long-Haul and Metropolitan Freight Travel Time Reliability", Journal of Transportation and Statistics, pp.83~89.

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