AIRPORT ACCESS BEHAVIOR OF TRAVELLERS UNDER RISK OF DELAY

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abstract: Travelers may behave risk-aversively when they are anxious about some risks due to arrival delay. Access travel behavior to an airport might be the typical case. Then in planning the access transportation to the airport this should be taken into consideration. However, no research has been done to analyze the risk aversive travelers' behavior in airport access. The present paper proposes an analytical model for the estimation of travelers' mode choice and departure time choice under risk of delay. The model is applied to the access behavior of travelers to Osaka International Airport and demonstrate its usefulness.

1. INTRODUCTION

Corresponding to the rapid increase of air transportation demand in Japan, development of airports as well as access transportation becomes more and more important. In planning airport and access transportation, precise estimation of travelers' behavior is required. For this purpose many kinds of models have been developed. The aggregate approach represented by gravity type models is most traditional. However this approach lacks accuracy even it is a quite convenient tool to estimate the demand for various transportation modes. In order to cover the fault of the aggregate approaches, disaggregate approach has been recently developed to explain individual traveler's behavior. This disaggregate approach is based on the description of individual utility by introducing such factors associated with rapidity, cheapness and convenience of transportation mode. However this approach dose not consider the risk aversive tendency of travelers, particularly in access transportation to the airport, because traveler's loss induced by uncertain arrival time at the airport is much more severe than that caused by other trips. Taking uncertain travel time into consideration, Matsumoto et al (1983), Hall (1983) and Uchida et al (1990) developed models to describe the risk aversive behavior of travelers. Those models mainly focus on traveler's choice of departure time from their origin, considering uncertain travel time due to congestion. Their approaches are quite likely to develop a model for airport access behavior.

There have been, on the contrary, researches associated with airport access from another viewpoint of approach. Ashford et al (1992) proposes an airport choice model based on simple nonlinear regression analysis. Even though it introduces various kinds of variables to explain the airport choice behavior of travelers, it fails to explain the mode choice to airport access transportation. Kishitani et al (1990) developed a huge linear multi-regression model

Figure 1 Major international airports in Japan

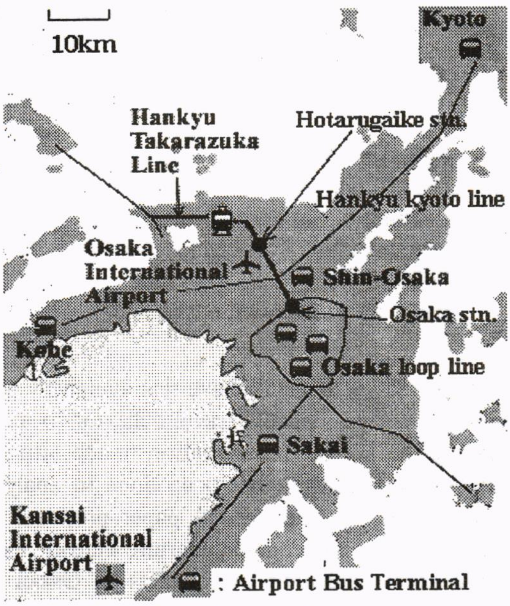

Figure 2 Hinterland area and major access transportation of OSA

to estimate the demand of access transportation to Kansai International Airport of Japan. It has unfortunately such a same defect as models of this type fatally include, that is, it needs huge size of data to estimate its endogenous parameters. On the other hand, Sumi et al (1986) developed a disaggregate type model to explain the traveler's airport access behavior considering the uncertain travel time. This is also quite suggestive for developing models of airport access behavior, but unfortunately it focuses only on the decision making of departure time under given access transportation modes. Another disaggregate approaches based on random utility considering uncertain travel time are given by Hagino et al (1994) and Yamasita et al (1996). They lack ,however, to analyze precise factors influencing on the traveler's behavior and stratification of individual attributes.

Taking these situations into consideration the present paper analyzes the factors influencing on travelers' airport access behavior and develops a model to estimate their departure time and modal choice based on questionnaire for the domestic passengers of Osaka International Airport.

2. AIRPORT ACCESS BEHAVIOR CHARACTERISTICS

2.1 Hinterland and Access Transportation

There are five major international airports in Japan as shown in Figure 1. The hinterland of Narita and Haneda International Airport covers the metropolitan area and eastern part of Japan, while Osaka International Airport (OSA) shares over Kinki region and Kyushu and western Chugoku region are the hinterland of Fukuoka International Airport. Questionnaire was distributed for the domestic air passengers at the check-in counter of Osaka International Airport in September 1993. It should be notified that the questionnaire survey

Table 1 Questionnaire Contents

Individual Information	Age, Sex, Occupation, etc
Fright	Flight number, Takeoff time(departure time)
Destination	Purpose of trip, Destination address, Details about destination
Origin	Origin address, details of origin
Travel behavior in access	Departure time at the origin, Reason of time choice. Actual arrival time, Expected arrival time at Osaka International airport Chosen Mode, a reason of modal choice.
Ordinary mode access in other days	Chosen Mode, a reason of modal choice.
Frequency	Frequency of using Osaka International Airport
Suggestions and opinions on access modes for Osaka International Airport	

was carried out before the open of Kansai International Airport (KIX) which is located offshore island near Osaka and opened in 1994. Therefore, the hinterland of OSA was not influenced by KIX at that time,

In Figure 2 are shown the hinterland area of OSA, main departing sites in the area (hereafter called as origin) and major access transportation. There are five major access transportation modes to OSA; railway (Hankyu Takarazuka Line), airport limousine bus, chartered bus, local liner bus, private car and taxi. When Hankyu Railway is used there are two kinds of means to approach the airport; local liner bus and taxi. It is connecting Hotarugaike near airport with the central districts of Osaka City and Kobe City, respectively. This railway has the advantage in punctuality than the others, but passengers must change mode at Hotarugaike Station. Limousine bus is, on the contrary, quite convenient because it connects directly airport with other major railway terminals of Osaka, Shin Osaka, Namba in Osaka City, Kobe, Kyoto and Sakai and serves by 15～20 minutes interval. However limousines as well as taxis are more risky because of delay due to traffic congestion and/or accidents in expressway. Local liner buses are limited to use only for travelers departing from the districts adjacent to airport even though it is not involved by the traffic congestion.. .

2.2 Outline of Questionnaire

Questionnaire was distributed for air passengers at the check-in counters of all airlines serving at Osaka International Airport in September, 1993, and returned by mail. Total number of questionnaire distributed was 3107, but 1248 of answer were returned, then the return ratio was 40 %. Articles of questionnaire are listed in Table 1. It asked personal attributes of individual air passenger, his flight, his origin and destination, time-related items, access transportation mode, and frequency of using Osaka International Airport and so forth. In time-related items, questionnaire asked his departure time and place (henceforth called as origin) with question why he chose his departure time, and actual travel time from origin to airport on the day with his anticipated travel time, it also asked transportation mode he chose with the question why he chose his transportation mode for airport access.

Table 2 Reason for choosing the access mode

	rapidity		punctuality		safety		comfort		no imformation of other mode		economy		other reason		total
Rail	45	38.1%	90	76.3%	12	10.2%	3	2.5%	1	0.8%	40	33.9%	2	1.7%	118
	51	37.2%	97	70.8%	14	10.2%	4	2.9%	1	0.7%	48	35.0%	3	2.2%	137
Airport bus	107	35.9%	145	48.7%	28	9.4%	22	7.4%	43	14.4%	121	40.6%	33	11.1%	298
	104	33.5%	147	47.4%	34	11.0%	29	9.4%	36	11.6%	149	48.1%	27	8.7%	310
Charter bus	1	3.2%	6	19.4%	3	9.7%	1	3.2%	3	9.7%	4	12.9%	17	54.8%	31
	0	0.0%	3	33.3%	3	33.3%	1	11.1%	1	11.1%	1	11.1%	1	11.1%	9
Local bus	24	30.0%	30	37.5%	6	7.5%	3	3.8%	17	21.3%	36	45.0%	6	7.5%	80
	25	29.4%	37	43.5%	9	10.6%	4	4.7%	14	16.5%	42	49.4%	8	9.4%	85
Private car	129	62.3%	71	34.3%	26	12.6%	59	28.5%	8	3.9%	24	11.6%	32	15.5%	207
	111	61.0%	65	35.7%	19	10.4%	56	30.8%	5	2.7%	21	11.5%	19	10.4%	182
Taxi	176	69.6%	81	32.0%	14	5.5%	60	23.7%	18	7.1%	2	0.8%	29	11.5%	253
	158	75.2%	74	35.2%	4	1.9%	49	23.3%	19	9.0%	1	0.5%	13	6.2%	210

upper level : on survey day lower level : most frequent use (multiple choice)

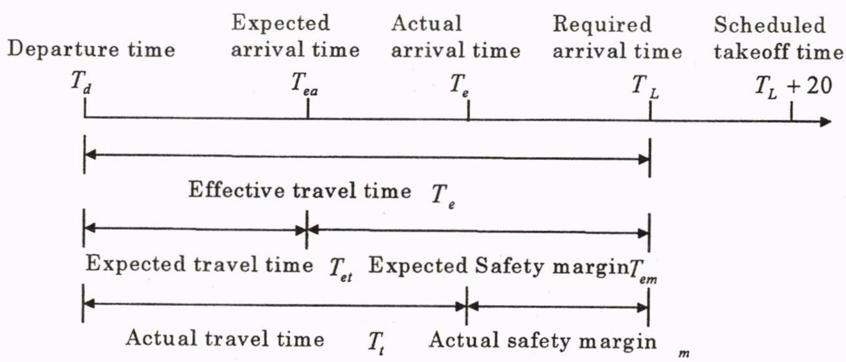

Figure 3 Definition of travel time in this research

The question of the choice reason of individual departure time is because there may be someone who want to spend time at airport for additional purpose such as shopping or eating and so forth. In that case he should leave his origin with some amount of time margin to avoid his delay while others may decide their departure time in order to avoid delay only due to uncertain travel time. Analysis should be carried out in each of these segmented groups. Questionnaire also asked how often individual passenger used the air transportation through Osaka International Airport and his usual access transportation mode.

2.3 Modal choice

In Table 2 is listed the summary of the questionnaire which shows access transportation mode and the reason of its choice. It should be noticed that answer is allowed to choose multiple items. In Table 2 the upper numbers are from the answers on the day surveyed and lower from the most frequent usage of the other days. From this table it can be said that punctuality is the most important factor for railway users, but private car and taxi users think rapidity is more important than punctuality, and bus users of both of limousine and liner do not make clear the reason for bus choice but consider punctuality and rapidity are relatively important.

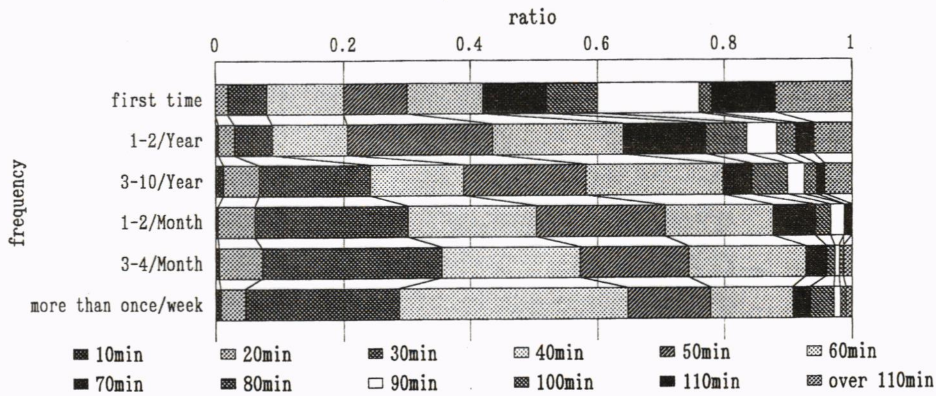

figure 4 Safety margin by frequency

2.3 Safety time margin

For risk aversive person it is very much important how much time he estimates for margin in order to avoid the delay of his arrival at airport under uncertain situation of his travel time. This time for margin is called as "safety time margin" in the present paper. He may leave his origin earlier than under situation of certain travel time and decide his departure time from the origin by estimating his real travel time taking account of the time when he should arrive at airport. In Figure 3 are shown the definition and relation of various time related to travel. T_d is the departure time from his origin, T_{ea} is the travel time individual traveler anticipates, T_a is the actual arrival time, and T_L is the time when traveler should arrive at airport in order to get on his scheduled flight(this is called as required arrival time), and in the present paper it is assumed as the time of twenty minutes before the departure time of his flight. Using above definitions, travel time and safety time margin are defined as follows;

effective travel time : $T_e = T_L - T_d$ (1)

expected safety margin: $T_{em} = T_L - T_{ea}$ (2)

expected travel time : $T_{et} = T_{ea} - T_d$ (3)

actual safety margin : $T_m = T_L - T_a$ (4)

actual travel time : $T_u = T_a - T_d$ (5)

In the above it should be notified that the actual arrival time is uncertain depending on the uncertain travel time from the origin to airport. Under this situation travelers must take his own safety time margin for each transportation mode based on his estimated travel time, however over estimation of the travel time, that is, safety time margin will result in opportunity loss for other activities. Taking these into consideration, questionnaire is analyzed.

Estimated Safety Time Margin and Travel Frequency

Figure 4 shows the relation between estimated safety time margin and travel frequency that travelers experienced. From this figure it can be said that the more travelers experience the trip, the less the safety time margin is estimated, that is, more than fifty minutes safety margin is estimated by 80 % of first experienced travelers, 55 % of monthly travelers, and 38 % of weekly travelers. This says that travelers tend to estimate smaller safety time margin through learning process.

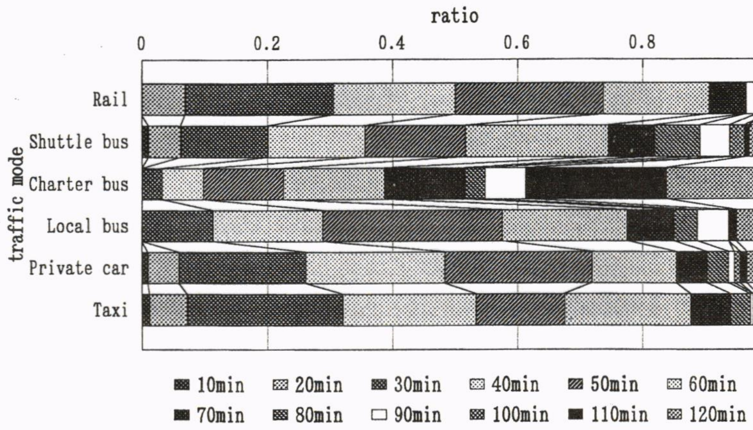

figure 5 Safety margin by mode

Estimated Time Margin and Mode Choice

Travelers may choose a more punctual transportation mode if uncertain travel time is anticipated. In fact, this can be seen in Figure 5 which shows the relation of estimated safety time margin and transportation mode resultantly chosen. The figure shows that railway users estimate a smaller safety margin than bus users. Although the railway travel time is less certain than car or taxi travel time, railway users' safety margin is as small as car users'.

It is notable that chartered bus users tend to estimate biggest amount of safety time margin. This may come from the fact that the travel agency schedules a large time margin because he does not want to compensate travelers for loss induced by delay and/or any other troubles Car and taxi users as well as buses or shuttles and liners have a similar tendency. Consequently it can be said that the transportation mode has less effect on the estimation of safety time margin.

Safety Margin and Origin District

Generally speaking it might be said that the longer the trip is, the more uncertain the travel time is. Therefore travelers whose access distance to airport is longer may take bigger safety time margin. Under this hypotheses, a regression analysis is carried out, the results is

$$E_j(T_{em})=36.50+0.28\,\mu_j \qquad (R^2=0.43) \qquad (6)$$

μ_j : average of actual travel time from origin zone j

This result is also supported by the research results of Kato et al (1986) associated with commuting trips as shown in Eq.(7).

$$E_j(T_{em})=1.89*\,\mu_j^{\,0.492} \qquad \text{(By Kato } et\ al\text{)} \qquad (7)$$

In Eqs. (6) and (7), total travel time is used in stead of distance because distance including different modes can be represented by travel time. Kato et al also present in their paper that safety time margin depends upon the standard deviation of travel time. Same results are also obtained by regression analysis for airport access data: Those are

$$E_j(T_{em})=14.58+0.196\,\sigma_j \qquad (R^2=0.211) \qquad (8)$$

$$E_j(T_{em})=35.01+0.350\,\mu_j+0.314\,\sigma_j \qquad (R^2=0.598) \qquad (9)$$

σ_j : standard deviation of actual travel time from origin zone j

Eq.(9) says that the safety time margin depends upon not only the standard deviation but also mean of the travel time.

Safety Margin and Personal Attributes

Estimated safety time margin may be depend on such personal characteristics as trip purpose, travel experience and occupation. From this point of view questionnaire is analyzed by Quantification Theory of Type I . Samples used for analysis excludes those samples as show extremely big safety margin because they are come from the travelers who have additional purpose such as shopping, eating and others after arrival at airport. As this consequence, 676 samples are analyzed. Results are shown in Table 3. In the table Model A is the case that picks up only mean travel time as the explanatory variable, Model B includes mean and standard deviation of travel time, and Model C through Model H are the cases that included explanatory variables associated with personal attributes are changed, and Model I includes all the variables..

As already analyzed individually, mean and standard deviation of travel time are the factors to influence on the safety time margin (refer to Model A and Model B). Comparing with Model B, it is understand that Model C through Model H have better coefficient of determination. Thus it is clear that the safety time margin is influenced by not only the travel time but also travel frequency (Model C), trip purpose (Model D) and occupancy (Model E). It is notable that the coefficient of determination of Model I is remarkably bigger than the others and t-value itself odes not decrease significantly. Therefore it can be concluded that all factors employed here should be considered for estimation of safety margin. It is also noticeable to observe the parameter's value of Model C that inexperienced travelers tend to estimate bigger safety time margin.

3. UTILITY FUNCTION CONSIDERING DELAYED PENALTY

3.1 Formulation

In the previous chapter it is statistically demonstrated that an individual air passenger holds some amount of safety margin in order to avoid the delay for his required arrival time. This is easily anticipated because air passenger will take great amount of disutility due to loss of time. The present chapter analyzes the disutility of delay by introducing Utility Function Type Avoidance Lateness.

UFTAL is a kind of traditional utility function, which was introduced by Hall (1983) and Uchida et al (1990). It is composed of penalty parameter and probability of delayed arrival as shown in Eq. (10).

$$V_i = -T_{ei} + \gamma_i * P(T_{di}) \tag{10}$$

where V_i is the specific traveler ***i***'s expected utility, γ_i the penalty of delay, P(T_{di})the probability of occurrence of delay (probability that the traveler i can not arrive at airport before his required time T_L when departure time at origin is T_{di}).

Table 3 Factor of safety margin (by Quantification method of type I)

dependent variable : safety margin (=required arrival time-expected arrival time)

independent variable		model-A parameter	model-A t-value	model-B parameter	model-B t-value	model-C parameter	model-C t-value	model-D parameter	model-D t-value	model-E parameter	model-E t-value
average of travel time		0.18	7.74	0.14	3.68	0.07	1.90	0.05	1.42	0.13	3.47
standard deviation				0.16	1.09	0.27	1.96	0.33	2.39	0.15	1.09
frequency	first time					19.47	5.08				
	1-2/Year					13.12	5.84				
	3-10/Year					6.02	3.11				
	1-2/Month					2.21	1.12				
	3-4/Month					-0.23	-0.11				
	1-2/Week					0.00	0.00				
purpose of trip	business							-10.14	-3.50		
	sightseen(individual)							-2.91	-0.90		
	sightseen(group)							10.25	2.84		
	going hometown							-2.20	-0.52		
	other							0.00	0.00		
occupation	employed									-9.98	-4.88
	unemployed									0.00	0.00
intercept		14.58		13.96		11.07		23.43		23.32	
standard error		16.75		16.75		16.09		15.96		16.44	
coefficient of determination		0.07		0.07		0.15		0.16		0.10	

independent variable		model-F parameter	model-F t-value	model-G parameter	model-G t-value	model-H parameter	model-H t-value	model-I parameter	model-I t-value
average of travel time		0.03	0.81	0.07	1.94	0.05	1.41	0.03	0.84
standard deviation		0.36	2.63	0.26	1.86	0.31	2.28	0.35	2.54
frequency	first time	12.64	3.21	18.01	4.69			11.79	3.00
	1-2/Year	9.27	3.83	10.99	4.72			8.46	3.48
	3-10/Year	4.38	2.27	5.23	2.69			4.07	2.11
	1-2/Month	2.25	1.16	1.98	1.01			2.05	1.06
	3-4/Month	-0.08	-0.04	-0.37	-0.17			-0.30	-0.14
	1-2/Week	0.00	0.00	0.00	0.00			0.00	0.00
purpose of trip	business	-7.18	-2.61			-6.71	-2.32	-4.58	-1.57
	sightseen(individual)	-4.32	-1.35			-1.67	-0.52	-3.19	-0.99
	sightseen(group)	8.40	2.35			12.63	3.50	10.47	2.87
	going hometown	-2.79	-0.66			-3.59	-0.85	-3.85	-0.92
	other	0.00	0.00			0.00	0.00	0.00	0.00
occupation	employed			-5.98	-3.27	-6.46	-3.16	-5.26	-2.57
	unemployed			0.00	0.00	0.00	0.00	0.00	0.00
intercept		18.57		17.12		26.47		21.44	
standard error		15.77		16.00		15.87		15.71	
coefficient of determination		0.18		0.16		0.17		0.19	

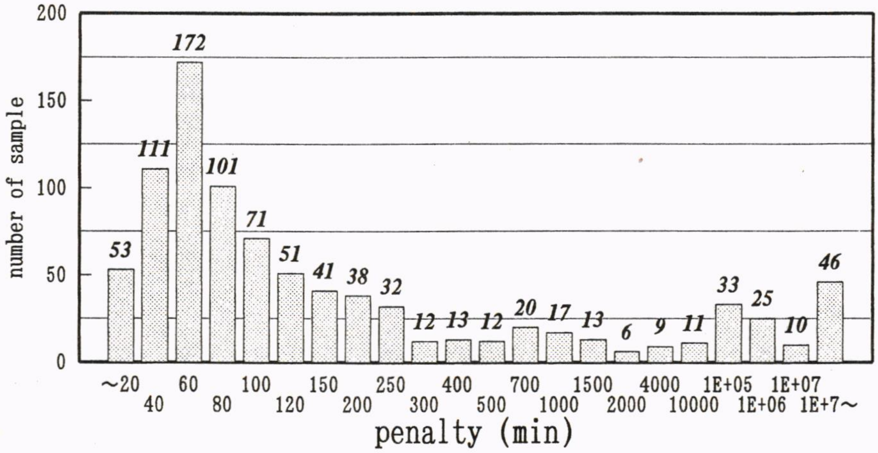

Figure 6 Distribution of penalty of delay

$$T^*_{di} = T_L - \mu_j - \sigma_j \Phi^{-1}(\frac{\sigma_j}{\gamma_j}) \quad (11)$$

where $\Phi^{-1}(\bullet)$ is the inverse function of Cumulative Normal Distribution function.

Solving of Eq.(11) yields

$$\gamma_i = \frac{\sigma_j}{\Phi(\frac{T_{iL} - T_{di} - \mu_j}{\sigma_j})} \quad (12)$$

It should be noticed in Eq.(12) that the penalty of delay, γ_i, is evaluated by the unit of time. Applying Eq. (12) to the samples obtained by questionnaire, the penalty of delay is distributed as shown in Figure 6. Even though the estimated penalty is widely distributed, most of travelers consider his delayed penalty as 40~80 min. This might seem smaller than the expected, but this might be equivalent to big monetary value if the time value of individual person is measured.

3.2 Factor influencing on delayed penalty

As previously discussed, estimated penalty for delay is widely distributed. This may come from difference of individual characteristics. Business trips and sight seeing trips may give different amount of penalty, and experience of travel may result in different value of penalty. The present section analyzes the factors influencing on the value of delayed penalty by using again Quantification Theory Type I . In the analysis the explanatory variables are considered as occupation, trip purpose and travel frequency experienced. The results are shown in Table 4. The coefficient of determination of Model I is greater than those of Model II and III, while Model I has more parameters than Model II and Model III. Therefore, it is impossible to decide which model is better. Associated with the travel frequency experienced, the frequency is smaller, the greater the value of parameter is. Then it could be concluded that travelers who experienced more frequently tend to feel greater amount of

Table 4 Factor of delay penalty (by Quantification method of type I)

dependent value: log(penalty of delay)		model-I parameter	t-value	model-II parameter	t-value	model-III parameter	t-value	model-IV parameter	t-value	model-V parameter	t-value
frequency	first time	**0.58**	2.73					**0.39**	1.77		
	1-2/Year	**0.61**	5.45					**0.50**	4.24		
	3-10/Year	**0.31**	3.41					**0.27**	2.98		
	1-2/Month	**0.21**	2.37					**0.22**	2.44		
	3-4/Month	**0.14**	1.45					**0.14**	1.50		
	1-2/Week	**0.00**	0.00					**0.00**	0.00		
purpose of trip	business			**-0.17**	-1.24			**-0.07**	-0.51	**-0.07**	-0.51
	sightseen(individual)			**0.14**	0.85			**0.08**	0.51	**0.08**	0.51
	sightseen(party)			**0.63**	3.04			**0.58**	2.79	**0.58**	2.79
	going hometown			**-0.01**	-0.06			**-0.06**	-0.28	**-0.06**	-0.28
	other			**0.00**	0.00			**0.00**	0.00	**0.00**	0.00
occupation	employed					**0.25**	4.57			**0.39**	1.77
	unemployed					**0.00**	0.00			**0.00**	0.00
intercept		**3.84**		**4.20**		**3.98**		**3.90**		**3.90**	
standard error		**0.69**		**0.69**		**0.70**		**0.69**		**0.69**	
coefficient of determination		***0.053***		***0.048***		***0.030***		***0.075***		***0.075***	

		model-VI parameter	t-value	model-VII parameter	t-value
frequency	first time	**0.56**	0.22	**0.38**	1.72
	1-2/Year	**0.58**	0.11	**0.50**	4.15
	3-10/Year	**0.30**	0.09	**0.27**	2.94
	1-2/Month	**0.21**	0.09	**0.22**	2.40
	3-4/Month	**0.14**	0.10	**0.14**	1.46
	1-2/Week	**0.00**	0.00	**0.00**	0.00
purpose of trip	business			**-0.03**	-0.24
	sightseen(individual)			**0.10**	0.58
	sightseen(party)			**0.61**	2.87
	going hometown			**-0.07**	-0.32
	other			**0.00**	0.00
occupation	employed	**-0.08**	0.10	**-0.07**	-0.68
	unemployed	**0.00**	0.00	**0.00**	0.00
intercept		**3.92**		**3.94**	
standard error		**0.69**		**0.69**	
coefficient of determination		***0.054***		***0.076***	

penalty. However this conclusion seems contradictory to our experience under the assumption of perfect information, expectation rationality and same subjective standard deviation of travel time for all travelers. Thus quantification analysis is again carried out for the groups of samples of which delayed penalty are relatively small. Those results are also shown in Table 4 as ModelIV、ModelV, ModelVI, and ModelVII. The results says that Model VI is inferior to Model V and Model VI in the sense that its coefficient of determination is smaller than the others、 Taking into consideration that Model I and ModelVIdo not show good fitness, it is clear that there is a multiple-collinearity between frequency and occupation. Among ModelsIV, VandVI, there are no remarkable difference. Then it can be concluded that ModelVis optimal and that frequency of travel experience is not suitable as the explanatory variable for delayed penalty.

However, coefficients of determination are low in table 4, it appears that the penalty for delay is independent of individual factors. Hence, we don't have to consider the relation between the parameter of delay risk and individual factors when we estimate demand traffic value by aggregated logit models.

4.CONCLUDING REMARKS

The present paper treats traveler behavior in airport access trips. Safety time margin held by individual passenger, modal choice and penalty for delayed arrival are statistically analyzed based on a questionnaire distributed to passengers at Osaka International Airport. The analysis is concluded as follows;

1) Punctuality is an important factor for airport access mode choice, especially for rail mode.
2) Safety time margin for avoiding delayed arrival at the airport strongly depends upon the mean and standard deviation of total travel time from origin to airport.
3) It is statistically estimated that travelers feel that their penalty of delay is 40-80 minutes.
4) The penalty for delay is independent of other individual factors, purpose of trip, age, and occupation.

Following this result, in the next stage we will try to develop a disaggregated logit model that estimate traffic demand and modal choice considering uncertainty of travel time. If the penalty for delay depends on individual factors, the utility function of the logit model would be quite complicated. However, fortunately the penalty is independent of individual factors following the present paper, we can easily deal with penalty of delay like cost factor and travel time factor. We expect that the uncertainty factor will be effective for the logit model. Because, the safety margin analysis in the present paper (Table 3 or eq.(9)) shows that the uncertainty factor is important for traveler's behavior when he/she chooses a traffic mode.

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