Passenger Characteristics and their Mode Choice between Air Transport and High Speed Rail in China

Shuyang KANG[1], Shinya HANAOKA[2], Makoto TSUKAI[3]

[1]Non-Member of JSCE, Graduate School of Science and Engineering, Tokyo Institute of Technology
(2-12-1-I4-12, O-okayama, Meguro-ku, Tokyo, 152-8550, Japan)
E-mail: ksykangkings@gmail.com
[2]Member of JSCE, Associate Professor, Graduate School of Science and Engineering, Tokyo Institute of Technology
(2-12-1-I4-12, O-okayama, Meguro-ku, Tokyo, 152-8550, Japan)
E-mail: hanaoka@ide.titech.ac.jp
[3]Member of JSCE, Associate Professor, Graduate School of Engineering, Hiroshima University
(1-4-1, Kagamiyama Higashi-Hiroshima City, 739-8527, Japan)
Email: mtukai@hiroshima-u.ac.jp

In recent years, the high-speed railway develops rapidly in China, which solves the problem that the transportation supply is not adequate to the passengers demand but also has a great impact to the air transport industry. Because of the high-speed rail lines that have been operating, passenger traffic of civil aviation industry has a huge loss, resulting the flights into reduce and certain routes of several airlines into suspend, which will bring a redistribution to the transport model share in China. In this research, passenger characteristics analysis and mode choice model estimation are conducted by data collection in stations and airport in Beijing. Firstly, the factors that affect traveler's choice behavior are analyzed and decided in this research. Then, the passenger's characteristics are analyzed based on the RP and SP data. Finally, logit model is chosen to estimate the mode choice model of high-speed railway and air transport.

Key Words : *Intercity Transport, RP and SP survey, Mode Choice Model*

1. INTRODUCTION

At present, China is in the period of rapid high-speed railway construction and development. After the first passenger dedicated high-speed railway line opening in 2003 in China, which is faster than 200 km per hour, several significant lines such as the Beijing-Shanghai line (1,318 km), the Beijing-Guangzhou line (2,298 km) were completed in 2011. Until September of 2013, the total mileage of China high-speed rail reached almost 10,500 km. By reviewing the "Mid-long term railway network plan" revised in 2008, more than 16,000km passenger dedicated high-speed railway line, which includes the most typical lines "Four vertical and four horizontal lines", will be built until 2020. At that time, there will be about 16,000 km high-speed railway lines in China, which will cover almost 90% of the China population and connect the capital cities and metropolis.

On the other hand, although the development of high-speed rail solves the problem that the transportation supply is not adequate to the passengers demand, it brings a great impact to the air transport industry. Because of the high-speed rail lines that have been operating, passenger traffic of civil aviation industry has a huge loss, resulting the flights into reduce and certain routes of several airlines into suspend, which will bring a redistribution to the transport model share in China.

In 2011, because of the completion of the Beijing-Zhengzhou high-speed railway line, flights demand between this two cities decreased nearly 20% and finally suspended in Feb. 2011. In the same year, after the opening of Bejing-Shanghai line, airfare kept 30% discount and all the flights between Nanjing to Jinan are suspended in Oct. In Nov. 2012, two airlines canceled all the flights between Dalian and Changchun because of the completion of Harbin-Dalian line.

From the examples showing above, it is easy to know the competition between high-speed rail and air transportation has already become an inevitable war. However, orderly competition in some degree will ease the pressure of domestic transportation, reduce the transportation cost and improve the qual-

ity of the transportation service.

In this paper, firstly, the factors that affect traveler's choice behavior are analyzed and decided. Based on these factors, case study are done by designing and conducting revealed-preference (RP) survey and stated-preference (SP) survey. Secondly, the passenger's characteristics are analyzed based on the RP and SP data. Finally, the transport mode share model are structured and estimated by using the RP and SP data.

2. CURRENT CONDITIONS OF HSR AND AT in China

(1) High-speed Rail (HSR) development in China

The definition of high-speed rail are also different in each country. In China, the railway transportation system which have the average speed of about 160 km per hour and the highest speed of more than 200 km per hour can be defined as high-speed rail. Furthermore, China's high-speed rail can be divided into two levels, which are the splinter rail and the full high-speed rail. The splinter rail, which can be also called "Dongche", has a maximum speed of 200-250 km per hour. The full high-speed rail, which can be also called "Gaotie", has a maximum speed of more than 300 km per hour.

Over the past decade, China has undergone a high-speed rail building boom with generous funding from the Chinese government's economic stimulus program. Until 2020, 16,000 km of passenger dedicated high-speed railway lines will be completed.

(2) Air Transport (AT) development in China

The definition of aviation is the activities that using aircraft to conduct the business passenger and freight transportation. In this paper, the passenger transport of civil aviation transportation is discussed.

The passenger transport airplane has the speed of about 800-900 km per hour. Until 2010, there are 1,880 civil aviation routes, including 302 international routes and 1,578 domestic routes. There are 175 civil airports and 2,405 civil airplanes.

After the recombination of civil aviation in 2003, the passenger traffic volume of civil aviation grew steadily. From 2009, year-on-year growth kept decreasing.

Until 2011, there are 47 airlines in China. Among these 47 airlines, 4 main airlines occupied almost 90% of transportation turnover volume. They are Air China, China Eastern Airlines, Southern Airlines and Hainan Airlines.

(3) Competition between HSR and AT in China

Both of the high-speed rail and air transportation have the advantages of safe, convenient, comfortable and so on. Some technology characteristics are compared as bellows:

a) Time value

By comparing the speed of high-speed rail and air transportation, the shorter the journey is, the more obvious advantage the high-speed rail has. When the journey is shorter than about 1,000 km, passengers prefer to choose high-speed railway. On the other hand, when the journey is longer than about 1,000 km, passengers prefer to choose air transportation.

b) Construction investment

In order to construct a high-speed railway line, facilities like stations and rails are necessary. This brings a huge investment and high risk to the construction. To open a 1,000 km routes, civil aviation line will cost 0.5 billion RMB but high-speed rail line will cost 2 billion RMB.

c) Operation cost and capacity

High-speed rail has the characteristics of large transport capacity and high density. The capacity of a normal high-speed rail is about 600-1200 people. On the other hand, airplane needs very high power and high cost to transport and the largest capacity is less 500 people. Therefore, the high-speed rail has a lower operation cost and larger capacity.In order to construct a high-speed railway line, facilities like stations and rails are necessary. This brings a huge investment and high risk to the construction. To open a 1,000 km routes, civil aviation line will cost 0.5 billion RMB but high-speed rail line will cost 2 billion RMB.

d) Punctuality

The weather change has a stronger influence on air transportation than high-speed rail. The high-speed rail has a strong regularity and a stronger punctuality than air transportation.

Some of the technology characteristics above can affect traveler's choice behavior, such as time value and punctuality. These 2 characteristics are belong to the transport characteristics. Other transport characteristics include fare, speed, security, convenience and comfortableness. Moreover, travelers and trip characteristics can also affect traveler's choice behavior. For example, personal imformation like gender, age, occupation and imcome are travelers characteristics. Purpose, distance, access time, waiting time and line haul time are belong to trip characteristcs.

3. METHODOLOGY

(1) Discrete choice model

Discrete choice model is a kind of model that observes choices made by individual travelers, which enable realistic models to be developed. The theoretical framework of this model is the probability of individuals choosing a given option is a function of their socioeconomic characteristics and the relative attractiveness of the option.

In this paper, two kinds of discrete choice models are structured. They are multinomial logit model (MNL) and nested logit model (NL). In this paper, traveler's choice behavior are analyzed under 2 purposes, business and non-business, by taking access cost, access time, ticket fare and frequency as the main variables.

The equation to estimate the model is expressed as below:

$$\boldsymbol{P}_{iq} = \frac{e^{V_{iq}}}{\sum_{Aj \in A} e^{V_{jq}}} \qquad (1)$$

In this model, V is the utility person q obtains from choosing i, together with the person and alternative specific error term, which is expressed as following sample:

$$V_i = \alpha_i + \beta_{1i}\boldsymbol{t} + \beta_{2i}\boldsymbol{c} + \beta_{3i}\boldsymbol{I} + \cdots \qquad (2)$$

$\boldsymbol{P}$ means the probability that person q chooses i. $i \in$ A={HSR, AT}. $\boldsymbol{t}$ is the travel time, $\boldsymbol{c}$ is the ticket fare cost, $\boldsymbol{I}$ is the income, can be divided into different levels. α_i, β_{1i}, β_{2i}, β_{3i}, β_{4i} are parameters.

The estimation of the MNL and NL results is necessary. The number of cases is defined as the sum of the number of alternatives available to each observation minus the number of observations. ρ square is an informal goodness of fit index that measures the fraction of an initial log likelihood value explained by the model. The value of ρ square will depend on the type of model being estimated and the results will be enough compatibility when ρ square is around the range of 0.2-0.4.

(2) RP and SP survey

There are mainly 2 investigation methods, revealed preference (RP) survey and stated preference (SP) survey. RP survey is only used for actual plan and based on the existing choice behavioral data. Therefore, it has a high accuracy. Its investigaion cost is high because only single data is available from an individual. While SP survey can be used for ideal plan because it is based on choices under designed scenario, which makes it a high randomness. The cost of this survey is low because multiple data are available from an individual.

4. DATA COLLECTION

(1) O-D information

Data collection is done in Beijing from December 6, 2013 to December 19, 2013. The reason why choose Beijing as the origin is not only because Beijing is the capital city, but also it is the departure or destination city of several main operational high-speed railway lines. In order to analyze the competition between high-speed rail and air transportation in China, cites that both have a high-speed rail station and an airport are inclined to be chosen. In this research, Jinan, Nanjing, Shanghai, Hangzhou, Qingdao that on the south direction Beijing-Shanghai line, Taiyuan, Zhengzhou, Xi'an, Wuhan that on the west direction Beijing-Guangzhou line, Shenyang, Changchun that on the north direction Beijing-Harbin line, total 12 cities are chosen to be the destination cities. These 12 cities are divided into 3 groups, cities marked with NO. 1,2,3 belong to the long distance group (1000-1300 km), NO. 4,5,6,7 belong to the middel long distance group (700-1000 km), NO. 8, 9, 10, 11, 12 belong to the middle distance group (300-700 km). Because the distance of some routes of high-speed rail and air transportaiton are much different in cities like Xi'an and Qingdao, the grouping of the cities are in accordance with the grouping of the aviation distance. Table 1, 2 shows the destination cities information (D: Distance, T: Line haul time, F: Frequency) departured from the 1 airport and 3 stations.

Table 1 Aviation O-D Information

NO.	Destination	D[km]	T	F
1	Hangzhou	1,147	2:00	40
2	Shanghai	1,075	2:15	69
3	Wuhan	1,054	2:05	22
4	Nanjing	948	2:00	18
5	Hefei	923	1:50	11
6	Xi'an	916	2:10	33
7	Changchun	869	1:45	25
8	Zhengzhou	663	1:35	8
9	Shenyang	607	1:30	20
10	Qingdao	538	1:25	27
11	Taiyuan	430	1:15	8
12	Jinan	362	1:05	4

Table 2 High-speed Rail O-D Information

NO.	Destination	D [km]	T	F
1	Hangzhou	1,591	5:55	9
2	Shanghai	1,328	5:15	28
3	Wuhan	1,200	4:45	14
4	Nanjing	1,162	4:05	36
5	Hefei	1,109	4:20	6
6	Xi'an	1,159	5:20	8
7	Changchun	1,032	6:45	8
8	Zhengzhou	695	3:05	27
9	Shenyang	889	5:25	18
10	Qingdao	819	4:45	7
11	Taiyuan	568	3:00	12
12	Jinan	498	2:10	61

(2) Questionnaire

In the RP survey questionnaire, there are total 14 questions. The respondents are all passengers waiting in check-in counter of airport or waiting room of train stations. The questions are about personal information (gender, age, occupation and income), trip characteristics (destination, trip purpose, access way, access time, access cost, departure region, one day return trip or not) and transportation characteristics (ticket fare, reason of choosing a certain transportation, reason of not choosing another transportation).

In the SP survey questionnaire, there are total 7 questions. The respondents are students in university, civil servants in government and residents on Internet. The questions are about personal information (gender, age, occupation, and income), choice behavior under 2 purposes (business and non-business) in 3 different distance levels (middle: 300-700 km, middle-long: 700-1000 km, long: 1000-1300 km) and influential factors. For SP survey, from one questionnaire can get 3 samples.

(3) Sample size

The real sample size is 840, 618 from RP survey and 222 from SP survey. The target size of each O-D set is decided by passenger volume and transportation frequency. The final effective sample size is 744, 532 from RP survey and 212 from SP survey.

5. RESULTS AND DISCUSSION

(1) RP survey passenger characteristics analysis

There are 267 air transport and 265 high-speed rail respondents in RP survey. Most of them are enterprise staff, student and self-employed.

a) Passenger characteristics

50% of elder people (elder than 35) choose using the high-speed rail, but only less than 20% elder people choose using the air transport. From the answer of some respondents, the shaking of airplane makes elder people feeling uncomfortable may be the main reason. Although airplane is the safest transportation at present, many people, especially elder people prefer to believe the real feeling rather than the statistic results.

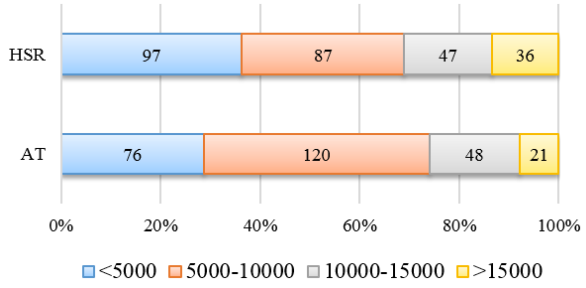

Fig.1 Household income/month (RMB)

Fig.1 shows the monthly household income level of the passengers. Although the passengers taking air transport of 5000-10000 level are more than the passengers taking high-speed rail in the same level, passengers belong to high income level (more than 10000 RMB) in taking high-speed rail are majority. This result is different from the common case study. One reason is that some respondents may care the invasion of privacy, become reluctant to give the real answer, instead responding randomly. Many respondents even did not answer this question.

b) Transportation characteristics

The ticket fare is divided into two segments, business and non-business. There is no obvious rule in each segment. Although the fare of high-speed rail is proportional to the distance, different classes and additional charges like insurance make the final fare uncertain. The fare of air transport are decided by the airlines in different situation. For example, although Jinan is the nearest city from Beijing in this 12 cities, The average ticket fare of Beijing to Jinan is the most expansive. By considering the low frequency of flights between Beijing to Jinan, few people prefer to choose air transport to go to Jinan. If keeping the low air ticket fare on this line, airlines will not be profitable.

c) Trip characteristics

Access mode of business and non-business trip are different showing in the following Fig.2 and 3:

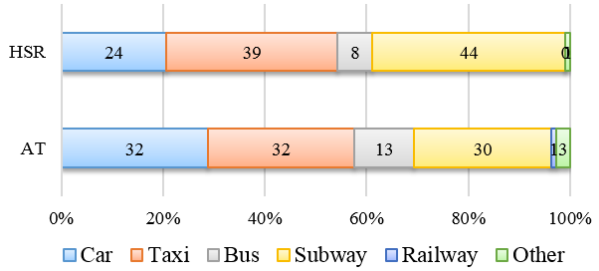

Fig.2 Access mode of business trip

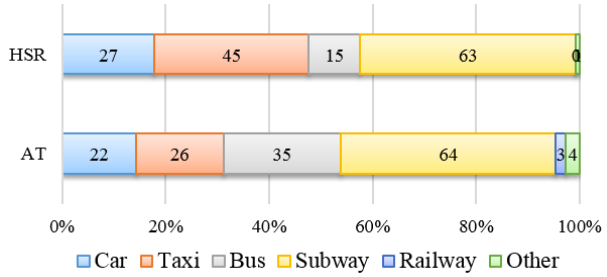

Fig.3 Access mode of non-business trip

In business trip, more people chose car or taxi as their access way. In non-business trip, people prefer to choose public transportation like subway or bus as their access way. In many cases, access time of car/taxi and public transportation are similar, but access cost are totally different. Public transportation are much cheaper than the car/taxi, which means for business purpose, people prefer to take easier access ways and for non-business purpose, people prefer to take cheaper access ways.

d) Determinant factors

Fig 4,5,6 and 7 shows the reasons that choose a certain transportation under two segments.

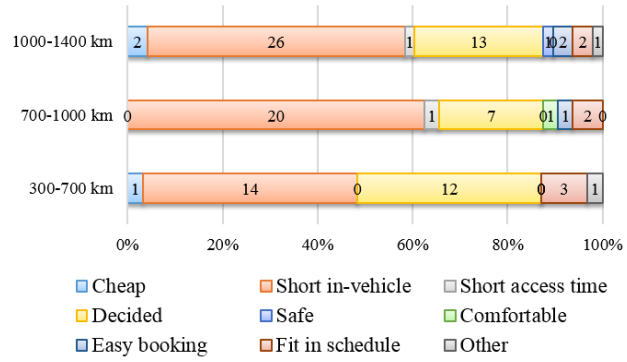

Fig.4 Reason of choosing AT of business trip

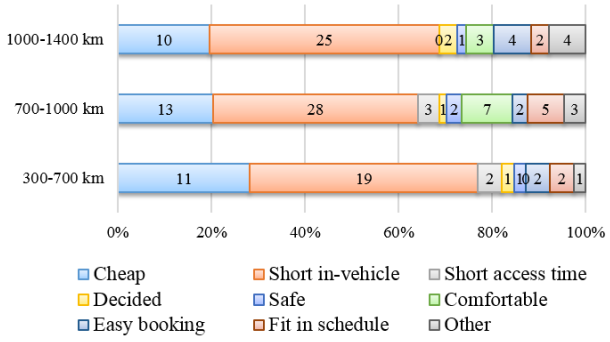

Fig.5 Reason of choosing AT of non-business trip

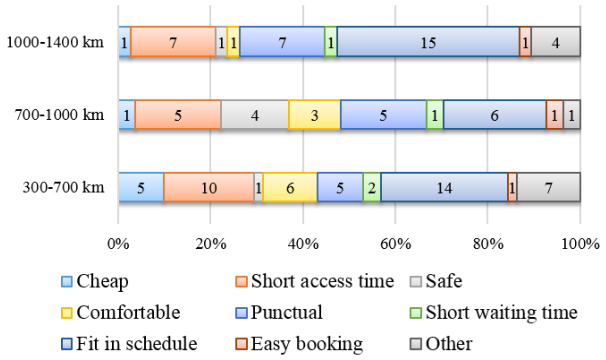

Fig.6 Reason of choosing HSR of business trip

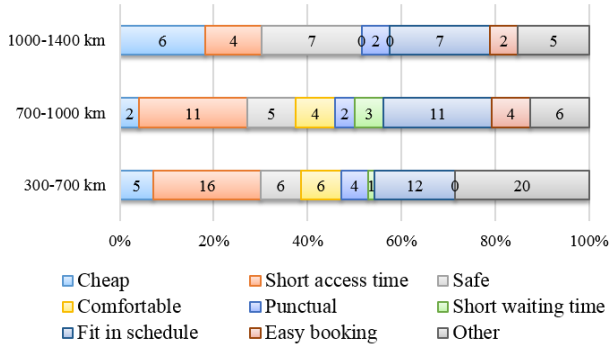

Fig.7 Reason of choosing HSR of non-business trip

Passengers choose air transport because of short line haul time and low ticket fare (reimbursement or discount). Passengers choose high-speed rail because of short access time, punctual, safe and fit in schedule. For different trip purposes, passengers choosing air transport to go to business trip concerned line haul time more and ticket fare less than non-business trip. Passengers choosing high-speed rail to go to business trip concerned punctuality more and safety less than non-business trip. Many passengers choose others as their answers because they think high-speed rail is very fast. Although it is slower than air transport, passengers choosing high-speed rail for non-business trip will not consider the fastness of air

transport. They think high-speed rail is already fast enough.

On the other hand, passengers do not choose air transport because of long access time, high ticket fare and not punctual. Passengers do not choose high-speed rail because of long line haul time. For different trip purposes, passengers do not choose air transport to go to business trip concerned access time more and ticket fare less than non-business trip. Passengers do not choose high-speed rail to go to business trip concerned line haul time less than non-business trip. When journey becomes shorter, more passengers do not choose air transport because of long access time. For business trip, more people do not choose air transport in short journey because of high ticket fare, on the other hand, for non-business trip, more people do not choose air transport in long journey because of high ticket fare.

(2) SP survey passenger characteristics analysis

There are 212 respondents in SP survey. Most of them are enterprise staff, institution staff and civil servant. More than 60% respondents are belong to 16-35 years old. Near 80% respondents are belong to 0-10000RMB income level.

a) Choice behavior

In SP survey, 3 samples are available from one respondent. Therefore, tripling the respondent's information becomes the following Fig.8 and 9.

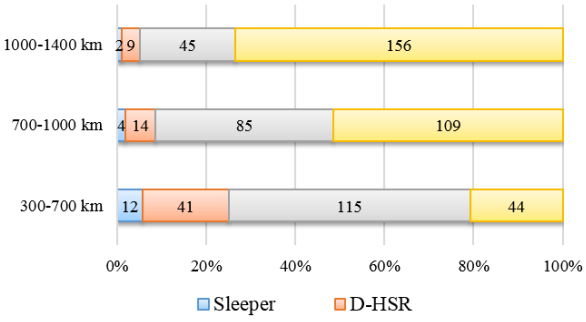

Fig.8 Mode choice under business purpose

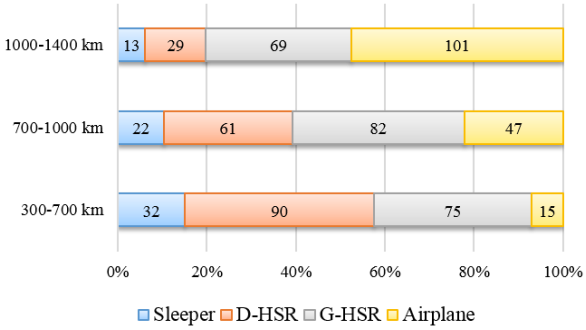

Fig.9 Mode choice under non-business purpose

The results of choice behavior of SP survey are obvious and regular. More people prefer to choose faster transportation for business trip and longer trip. Fewer people care ticked fare for business trip and longer trip.

b) Determinant factors

Fig.10, 11, 12 and 13 shows the reasons that choose a certain transportation under 2 segments.

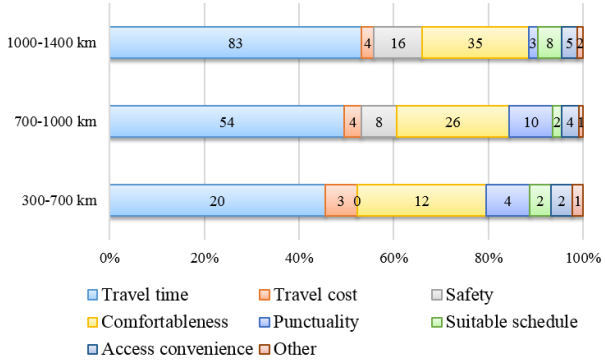

Fig.10 Reason of choosing AT under business purpose

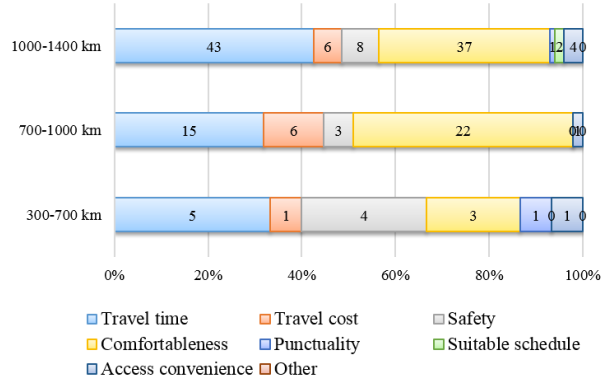

Fig.11 Reason of choosing AT under non-business purpose

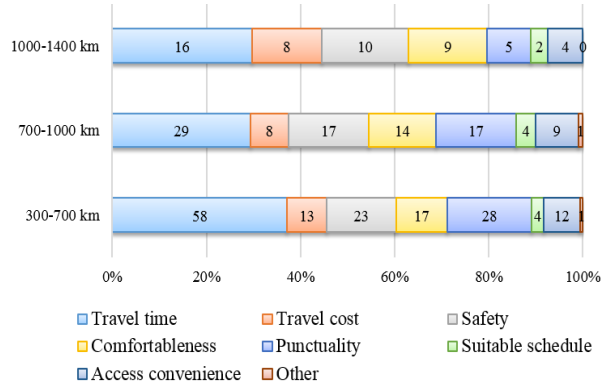

Fig.12 Reason of choosing HSR under business purpose

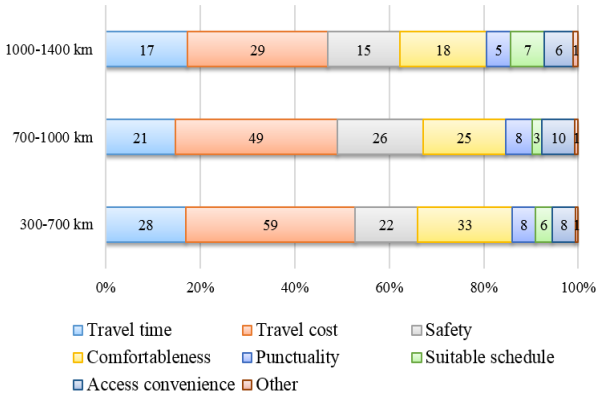

Fig.13 Reason of choosing AT under non-business purpose

For business trip, travel time is the dominant factor. Especially, more than 50% respondents choose air transportation because of short travel time for business trip. Respondents who choose high-speed rail to go for business trip, concerned not only travel time, but also safety, comfortableness and punctuality. For non-business trip, travel time, comfortableness and travel cost are dominant factors. Nearly 40% of respondents concerned travel time or comfortableness when choosing air transport to go for non-business trip. 35% of respondents who choose high-speed rail to go for non-business trip, concerned travel cost most and nearly 15-20% of them concerned travel time, safety and comfortableness most. Because specific origin and destination are not given, factors like access convenience and suitable schedule are not dominant factors.

(3) Mode choice model estimation

In this part, mode choice model are estimated by using RP data. A software called biogeme, a mode file (.mod) and a database file (.dat or .txt) are necessary. Mode file can be made by transforming from a certain text file. Database file can be made by a text file directly but the words should be separated by TAB. In order to make these 2 files, variables and models should be decided at first. In this case, nested logit and multinomial logit model (Air transport, access way is car or taxi / Air transport, access way is public transport / High-speed rail, access way is car or taxi/ High-speed rail, access way is public transport) are structured and access time, access cost, ticket fare, line haul time, income and frequency are decided as variables. The structure of the multinomial logit model is based on assumptions about the correlation of unobserved effects between alternatives and should not be interpreted as the passengers' decision. Since there are passenger information about which district area they come from, these information are available and assumed that the passengers are come from the center of each district. Different types of access time are calculated by information on the Internet. Since there is no information on access mode choice, assumption that passengers have a strict preference for short travel times, the fastest connection available, and always choose the same transportation as the reality data they chose in RP survey.

Access fare are estimated by 2 steps. If the passenger use public transportation, the access fare is estimated as normal public transport fare from the government of district to station or airport. In the situation passenger use car or taxi as access transportation, access fare is related with access time.

Table 3 MNL estimation result

Variables	MNL			
	Business		non-Business	
	Parameter	t-value	Parameter	t-value
access cost	-0.0266	-7.91	-0.0130	-5.79
access time	-0.0105	-2.09	-0.0042	-1.04
frequency	0.0208	2.11	0.0279	2.69
ticket fare	-0.0040	-4.35	-0.0077	-7.72
line haul time	-0.0041	-0.88	-0.0024	-0.55
Con. AT Car	2.02	2.13	4.24	4.38
Con. AT PT	-0.233	-0.24	3.73	3.86
Con. HSR Car	Fixed	-	fixed	-
Con. HSR PT	-2.23	-7.13	-0.791	-3.04
ρ square	0.370		0.320	
ρ square Adj	0.344		0.299	
sample size	224		276	

Table 4 NL estimation result

Variables	NL			
	Business		non-Business	
	Parameter	t-value	Parameter	t-value
access cost	-0.0253	-5.73	-0.0120	-5.48
access time	-0.0085	-1.99	-0.0034	-1.38
frequency	0.0163	2.00	-0.0007	-0.09
ticket fare	-0.0034	-3.48	-0.0044	-5.83
line haul time	-0.0029	-0.84	-0.0119	-2.27
Con. AT Car	1.83	2.30	0.492	0.68
Con. AT PT	-0.122	-0.17	0.274	0.34
Con. HSR Car	Fixed	-	Fixed	-
Con. HSR PT	-1.97	-5.67	-0.673	-2.37
ρ square	0.375		0.306	
ρ square Adj	0.343		0.280	
sample size	224		276	

Table 3 and 4 show the results of model estima-

tion. The estimation result of MNL and NL are similar. The estimated parameter of income is insignificant in each model. Access fare, ticket fare, access time, line haul time are all expected to show a negative effect on the utility of an individual. The opposite is expected for the frequency parameter, a large number of flights leads to a higher utility level.

Except the parameter of frequency of NL under non-business pupose, parameters of all this 5 main varriables have the expected sign and almost significant at the 95% confidence level. The t-test value of access time and line haul time under business purpose is bigger than the value under non-business purpose, which reflects the business passengers concerned access time and line haul time more. On the other hand, non-business passengers concerned ticket fare more.

6. CONCLUSION

In this study, passenger characteristics analysis based on RP and SP data and mode choice model estimation based on RP data are conducted by data collection in stations and airport in Beijing. 12 original-destination sets are decided as the survey target. From both RP and SP data, access time for high-speed rail and line haul time for air transport are dominant influential factors. Income is not a significant variable in the survey, which is different with the conmmon survey. The result of model estimation shows that the value of ρ square is big enough, so the model is persuasive. Access time, access cost, ticket fare and frequency turn out to be significant factors and their sigh of parameters also turn out to be expected.

ACKNOWLEDGMENT: The authors would like to express our gratitude to Jia and He from Tsinghua University for their moral support on data collection in Beijing and warm encouragements.

REFERENCES

1) Behrens, C. and Pels, E. (2009) "Intermodal Competition in the London-Paris Passenger Market: High-Speed Rail and Air Transport", Tinbergen Institute Discussion Paper, University of Amsterdam.
2) Zheng Zhao, (2009) "The Analysis about the Impact of the High-speed Railway Operation on Civil Aviation".
3) Mao, J. (2010) "Air vs Rail Competition towards the Beijing-Shanghai High-Speed Railway Project in China", Journal of Air Transport Studies, Vol.1, No.2, pp.42-58
4) Zhang, X. and Luan, W. (2010), "Research on Competition between High-speed Rail and Air Transport in China", 2010 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT), Vol.5, pp.642-646.
5) Centre for Aviation (CAPA) (2011), "Beijing-Shanghai Airfares Slump as High-Speed Rail Service Commences", News on 5th July 2011.
6) Yi Liu, (2013) "The Impact of High-speed Railway on Civil Aviation Transportation Industry".
7) "Year Book of China Transportation & Communications" (2013).
8) Japan Society of Traffic Engineers (2013) "Disaggregate Travel Demand Analysis ".

(Received April 25, 2014)