Explaining Adaptation Patterns to High Speed Rail Usage in Taiwan and China

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Understanding the gradual changes in travel behavior over time is essential to comprehending the association between travelers' adaptation process and travel demand. However, observing long-term travel behavior is generally difficult to obtain, details that triggered the changes might be missing via traditional cross sectional survey. The paper proposed a different approach on data collection methodology, which aims at analyzing the gradual changes of travel behavior on high speed rail (HSR) in Taiwan and China over the last 8 years. By developing graphical long-term usage patterns with detailed usage descriptions, changes and reasons to such usage were identified, the behavioral dynamics were captured from the overall sample. Detailed aspect involved with attitudinal factors, utility perceptions, past experience, and socio-demographic were further investigated. The results show that it can capture 98% of travelers' usage pattern and disclose detailed information on different level/degree of adaptation towards HSR over time. Multinomial Logit model (MNL) was applied to estimate parameters influence HSR usage among different groups of travelers. The MNL result suggests that fast adopters and those dropped usage at some point, shared similar characteristics compared to slow adopters. From the attitudinal factors, one's perceptions of "willing to try" has a positive impact on a person's likelihood to start using HSR. As for socio demographics, higher education degree and personal income would encourage travelers adopting HSR. A number of reasons to start using HSR are discussed and found to have different impacts on perceptions towards HSR among all travelers and regions.

Key Words : *Long-term travel behaviour, Data collection, Adaptation, High speed rail, MNL modelling*

1. INTRODUCTION

Long term travel behavior is difficult to observe and even more difficult to explain. Using survey methods respondents might recall key decisions, such as when they bought cars, when they changed their commuting pattern, but it is difficult to recall more detailed decisions. Such information is though of interest if one wants to understand the gradual change in behavior over time. In particular planners are interested in understanding the "adaptation process" of travelers to infrastructure investments and technology advances. In this paper we focus on the effect of introduction of high speed rail. However, the market entry of low cost airlines, the recent rise in usage of various shared mobility schemes or the near advent of autonomous vehicles are all further examples where one tends to expect an, over time, growing usage uptake. For each of these three cases, the reasons are manifold and vary but can all be at least partially linked to changing (or adapting) user attitudes and preferences.

Memory, habit, and past experiences form our preferences over time. Similarly, looking at long term usage patterns of a specific mode is the outcome of a (sometimes lengthy process) involving self-planning, initial perceptions of the new mode, receiving further information about it over time and reflecting previous experiences. Developing appropriate methodologies to capture long term behavioral dynamics is hence essential for transportation planners to understand the gradual changes of individuals to able to make population wide predictions.

The remaining of this paper is structured as follows. In **section 2**, we review hence first existing data collecting approaches which leads then to our

objectives which are to collect data about behavioral adaptation to high speed rail usage. **Section 3**, we describe the problem at hand that triggered our survey analysis and propose a new methodology to confront the issue. Details on other explanatory variables in the survey and the overall survey flow are discussed. **Section 4** reveals the usage pattern distribution from travelers and descriptive analysis on socio-demographics, in addition, we discuss the validation of proposed usage pattern via actual usage frequency. The initial MNL analysis of reasons on behavior changes is discussed in **section 5**. Finally, the paper concludes by discussing findings from the proposed survey as well as the usefulness and limitation of this approach.

2. DATA COLLECTION APPROACHES FOR OBSERVING LONG-TERM BEHAVIORAL CHANGES

A number of data collection/survey methodologies on observing long term behavior have been used in the literature. The standard approach is to collect data from a cross-section of the population at one point in time. Similarly, "repeated cross-sectional survey" collect data at several time points from independent samples of the population. A "Time series survey" is very similar to a cross-sectional survey, but distinguished by Pendyala and Pas[1] (2000). In addition to repeated cross-sectional data, it involves the collection of aggregate level data. Further, time series surveys must be carried out at regular intervals for many years or time points. For example census data that offer information at grouping level may be regarded as time series data. These data are well-developed tools for observing aggregate long term travel patterns. The statistics are typically used to compare travel differences in terms of means and proportions and are reflections of theme differences among the entire population. The advantages of cross-sectional surveys are that they offer a snapshot of conditions present at that instant (quickly amass data). While cross-sectional data provide sufficient data for determining overall population characteristics and trends over time, they may not be able to capture underrepresented population segments as for example Dowling and Colman[2] (1995) discuss with household travel survey data from San Francisco. Moreover, cross sectional data do not provide sufficient data for detailed behavioral analysis, measurement of change at disaggregated level, and most importantly, the cause-and-effect identification; where two distinct variables are measured at the same point in time. One may find from the modelling analysis that they are correlated, but cannot positively determine if one caused the other.

A possible direction to confront causality problems and to capture the complexity of decision making are panel surveys, also referred to as longitudinal data (Hsiao[3], 2007). Longitudinal surveys differ from the collection of repeated cross-sectional data as the behavior of independent samples can be tracked over time since at each "survey wave" the same individuals are surveyed (Yee and Niemeier[4], 1996; Kitamura[5], 1990). Another advantage of panel data is the simplifying computation and statistical inference. The design of longitudinal data is particularly well suited for stationary populations; in region wide transportation studies, this limits the inference to subjects residing long-term in a closed region. Panel data enable researchers to develop advanced behavioral models such as mixed logit and dynamic discrete choice models (Hsiao[3], 2007). However, one cannot ignore the additional cost of panel data which generally are much more expensive to collect than cross-sectional data. Time insensitivity is another limitation that makes it very difficult to obtain panel data; the survey would take several years and some of the observation usually drop out during the survey. Another major issue of panel surveys is that repeated measurements are likely to cause "survey fatigue problem". For further discussion we refer to a number literature comparing these survey methodologies such as Pendyala & Pas[1] (2000), Hsiao[3] (2007), and Yee & Niemeier[4] (1996).

Over the past decade, with the advancement of ICT "trajectory-based surveys" are increasingly complementing other forms of collecting panel data. GPS log data, smart card data, mobile phone data can all enhance the accuracy of behavioral records and are increasingly used in recent studies. The abundance of the emerging trajectory data has driven a new wave of travel behavior research, as they introduce new potentials as well as new problems (Yue[6] et al., 2014). Travel trajectory properties, such as origins and destinations (OD), departure and arrival times, trip purposes, and travel modes, can be extracted from such survey data and then fed into transport models. Though the majority of trajectory-based surveys focuses on daily/weekly patterns (Gong[7] et al., 2012; González[8] et al., 2008); also capturing longer term behaviour is possible. De Montjoye[9] et al. (2013) look at mobile phone records of 1.5 million people to model human mobility uniqueness over 15 months. For trajectory-based data, maintaining privacy is a primary issue. Other

challenges such as data sharing/obtain (different stakeholders), variation of models and algorithms, data bias, and data limitations are discussed in Giles[10] (2012) and Yue[6] et al. (2014).

Yet a different approach to capture long term travel behavioral changes are in-depth personal interviews. Such, to some degree qualitative, data, can help to fill the gaps left by quantitative techniques. The interview surveys are often used in circumstances when the issues under study are clearly defined and participant responses are, to some degree, anticipated. The survey instruments frame the questions and limit the range of answers to those questions. In-depth interviews have also become more popular since attitudinal factors have been increasingly shown to be important to understand travel behaviour (Clifton and Handy[11], 2003). The challenges of in-depth interviews are obvious: The survey is easily prone to biases, not generalizable (small samples, random sampling not available), could be time/labor intensive, and the interviewer must be appropriately trained.

In conclusion, the discussed data collection types differ with regard to the degree of behavioral dynamics observed and the potential analysis methodologies. Especially for our main interest, that is explaining gradual changes of travel behavior over several years, the above mentioned methods all have some drawbacks which we partially aim to overcome with a, what we believe, new survey approach where we ask users to choose between graphically represented patterns. The objective of this paper is to discuss the usefulness and limitations of our approach, for obtaining (very) long term behavioral data; in this case usage of high speed rail (HSR) over the last eight years.

3. MEASURING INDIVIDUAL LONG-TERM HIGH SPEED RAIL USAGE

(1) HSR in Taiwan and China

High speed rail is currently rapidly growing in Asia. The Taiwan HSR service connecting the island from north to south opened in 2007. In China the HSR network keeps increasing. Around Shanghai the service started in 2008. Looking at demand patterns, in particular the Taiwan case shows that despite supply characteristics, such as travel time and cost, staying fairly unchanged over time the demand has been continuously increasing. Demand predictions made before the opening of Taiwan HSR have though continuously overestimated the total demand (Cheng[12], 2010). Li[13] et al (2014) develop time series models controlling for socio-demographic and economic factors and conclude that the increase (on a below estimate level) is a mix of mode shift and induced demand. With aggregate data as used in this previous study a more detailed understanding of how such demand adaptation takes place, is though not feasible. In particular it is not feasible to understand how long, if ever, it takes for the demand to reach the predicted levels.

Further, at this stage, obtaining cross-sectional or panel data for retrospective observations seems not feasible. In particular, if we ask for HSR travel at specific points in the past, the respondent might not be able to answer, or, if he could answer, we might miss detailed information on events that might have occurred between the data collection points and triggered the change. Personal in-depth interviews could capture these variables and characteristics mentioned above, but efficiency consideration must be taken into account, especially as we aim to compare data collected from two specific regions. As such, we aim for our survey to be carried out via the internet, especially since our objectives are clearly defined but we want to reach a wide population group. We therefore develop a survey tool as described in the following section.

(2) Graphical Usage Patterns

The questionnaire consists of three main parts, the other two components will be described in Section 3. At the heart of the survey is the design of graphical usage patterns to describe individual's HSR usage over several years. In particular, 10 graphical hypothetical HSR usage patterns have been defined following a detailed description for respondents to select the abstract pattern that most fits to their actual long-term usage (see **Fig. 1**). In other words, respondents were asked to choose that specific pattern that best represents their usage pattern over time. We note that it might be difficult for respondents to recall their memory of HSR experience by just looking at each graphical hypothetical pattern; therefore, before asking about the patterns we ask some "usage recall questions" as discussed in Section 3.

Once recall questions are answered, 10 graphical hypothetical HSR usage patterns with text descriptions are displayed to respondents. The figures were defined as a coordinate system. The y-axis denotes HSR usage frequency without explicit numbers of trips; the x-axis from left to right denotes the timeline since the first time when the traveler starts using HSR until now, without the exact time period nor interval to represent time duration; therefore the

virtual coordinate (0,1) could represent the 1st time (1st trip) of individual start using HSR in the pattern. In order to examine the dynamic usage over time, the description of the patterns intents to split the timeline into several time period depending on usage pattern. The main information that we aim to obtain from the pattern selection are following:

1. Did the 1st time taking HSR trigger subsequent usage or was it a one-off usage?
2. In particular, did it take some time before a significant increase of HSR usage occurred?
3. If ever, did the usage significantly drop at some point?
4. If ever, does the traveler describe HSR usage as fairly stable or constant over a prolonged time period?
5. What is the current HSR usage?

Furthermore, based on the chosen pattern above, a set of specific questions (items) could be assigned to respondents;

A. Motivation to start using HSR
B. Reason/motivation to increase HSR usage
C. Reason for continuous, fairly stable usage of HSR over a prolonged time period
D. Reason/motivation to drop HSR usage

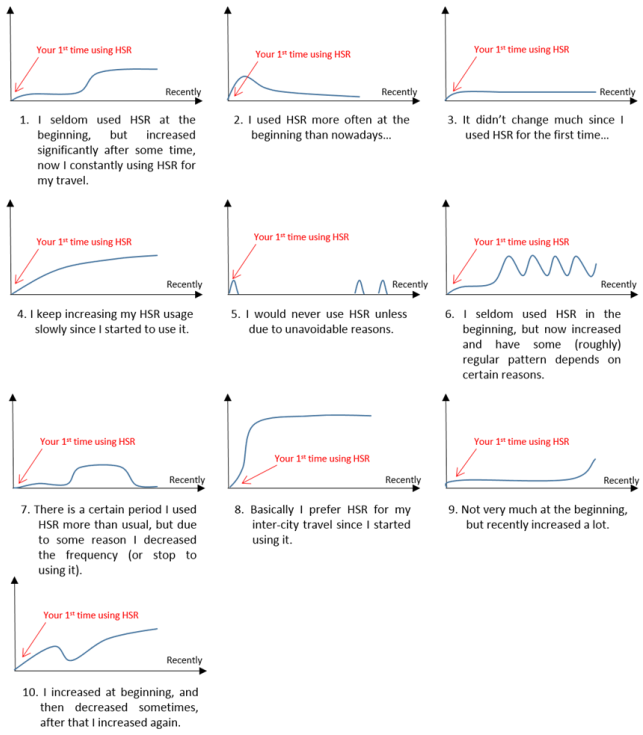


Fig. 1 Hypothetical HSR usage patterns.

The set of questions corresponding to A are perception related items such as "I expected HSR to be more convenient" and "friends encouraged me to use HSR", as well as factors related to perception on service attributes such as "speedy, time saving" (for details see **Appendix**). Some sections among B to D were then skipped depending on the chosen pattern. For example, if one chose Pattern 1 as his/her experienced HSR usage, Section A, B, and C will be included but section D (reduced HSR usage) is skipped; if Pattern 2 is chosen, sections A, B, and D will be included but Section C is skipped. Using pattern 7 as an example, the period of the section will be highlight in the graphical pattern for respondent to recognize before answering that section (see **Fig. 2**). The sections assigned to individual pattern see **Table 1**.

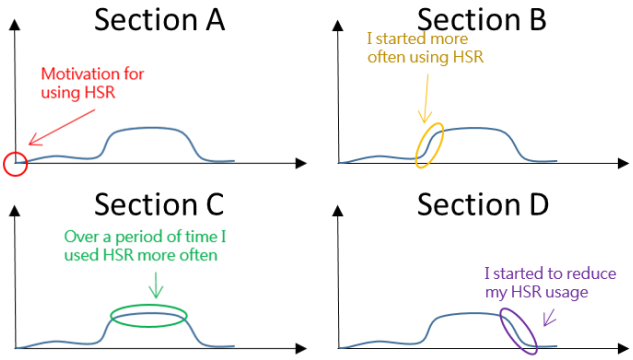


Fig. 2 Examples of section assigned to graphical pattern.

Table 1 Section Assigned To Graphical Patterns

Pattern	1	2	3	4	5
Section	ABC	ABD	A	ABC	AD
Pattern	6	7	8	9	10
Section	ABC	ABCD	ABC	AB	ABD2B

Each item in sections A, B, C, and D is posed on a 5-level Likert scale question to identify the importance of that item from 1 to 5 and are verbally described as: "Absolutely not the reason", "Unimportant reason", "Moderately important reason", "Important reason", and "The most important reason [to start using HSR/ to use HSR more/ to keep using HSR/ to reduce HSR usage]".

(3) Other Explanatory Variables and Overall Survey Flow

To explain the chosen pattern and to better describe the usage frequency associated with the patterns other variables such as attitudinal factors, recall questions, and socio-economic factors are obtained. This section discusses the detailed descriptions of these and the overall survey flow.

a) Recall Questions (Frequency and Trip Purpose), and Socio-Economic Factors

Regarding the usage patterns, we ask respondents to recall their HSR usage frequency and trip purpose during each two year period since opening of HSR. We ask these questions before asking for the usage patterns to arouse the respondent's memory in order to be able to identify the graphical pattern that describes their usage best. The questions are similar to the survey given in cross sectional and panel survey but less accurate since we suggest it is difficult to recall once precise usage frequency of a mode several years ago. Based on their vague impressions/memories, the HSR usage frequency and the type of trip mostly conducted during each time frame (period) were investigated. The usage frequency are rephrased as: can't remember, never, once/a round trip, a few times, monthly/almost monthly, weekly/almost weekly, daily/almost daily. Trip purpose was defined as commuting, business, return-home, and leisure trips.

The respondents were firstly asked about usage of this year (2014), then followed by the question of when they started using HSR. According to their answer, recall questions in chronological order are then asigned and continue till the last 2 years (2012~2013). These questions are expected as warm-up questions for the following graphic usage pattern.

Socio-economic factors were obtained in the survey as well. The respondents are asked regarding their most frequently HSR origin and destination (station), alternative travel mode, as well as socio demographics including gender, marital status, age, personal income, family income, level of education, car license, occupation, and residence. In addition, the survey includes attitudinal measures at the beginning of the survey, where innovativeness might also explain the usage pattern. A subscale of the commonly used scale proposed by Hurt[14] et al (1977) is included in our survey but do not focus on this in this paper. Full description of the innovativeness measures considered in this study enclosed in **Appendix**.

b) Overall Survey Flow and Survey Implementation

The overall survey flow chart is shown in **Fig. 3**. After a brief introduction about the purpose of the survey we firstly ask the innovativeness scale. We decided to pose these questions first, to avoid the influence of answers given to HSR usage on answers to this part. Next, a filter question is asked for screening those who had HSR experience and eligible to continue the survey. Following are the recall questions about the HSR usage frequency and the type of trip mostly conducted at each time frame (period). Then the ten hypothetical HSR usage patterns shown in Figure 1 are displayed to the respondents. According to the selected pattern, corresponding sections of items are than assigned (see Appendix). Finally, we asked travelers about their most frequently used HSR stations, their alternative travel mode in case HSR is not available as well as socio demographics.

The survey was coded via the online questionnaire website named "Surveymonkey" and responses collected from September to October 2014. In order to reach a wide population range, in Taiwan we recruited via an announcement in a popular Bulletin Board System (Ptt.cc). As an incentive, we awarded those completing the survey with virtual points that are commonly used as currency on the bulletin board. A value of 0.5$ USD of 500 "P points" were given. Similarly, in China, we recruited via an internet forum with a small incentive in the form of a mobile phone voucher for those who completed the survey.

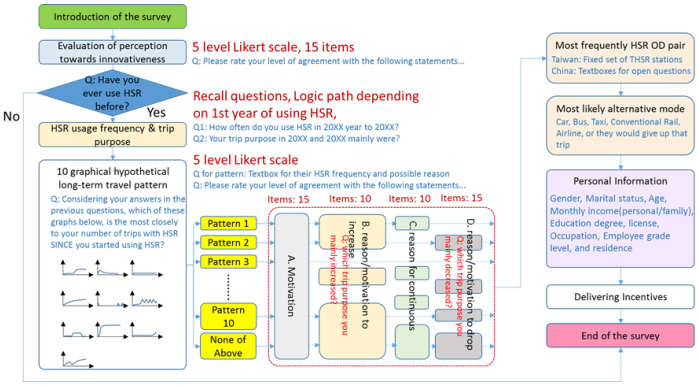


Fig. 3 HSR usage survey flowchart.

4. SOCIO-DEMOGRAPHICS AND PATTERN DISTRIBUTION

(1) Socio-demographics

We collected a total of 693 valid responses: 309 from Taiwan and 384 from Shanghai. **Table 2** shows the distribution of our sample in terms of socio-demographics. Clearly in particular male students are found to be overrepresented, possibly due to their higher likelihood of frequenting internet bulletin boards and answering online surveys. These biases should be kept in mind for our subsequent analysis. If one wants to obtain population representative statistics on adaptation behavior, a significantly larger sample size will be required.

Table 2 Descriptive Statistics

Socio-demographics		No.	%
Gender	Male	436	65.5%
	Female	230	34.5%
Marital status	Unmarried	493	74.0%
	Married	169	25.4%
	Other	4	0.6%
Education Degree	No university degree	34	5.1%
	Bachelor	344	51.7%
	Master	243	36.5%
	PhD	45	6.8%
Age	under18	6	0.9%
	18 - 25	271	40.7%
	26 - 30	231	34.7%
	31 - 35	94	14.1%
	36 - 40	31	4.7%
	41 - 45	14	2.1%
	46 - 50	8	1.2%
	51 - 55	7	1.1%
	56 - 60	3	0.5%
	over 65	1	0.2%
Monthly personal income (USD)	0 - 500	340	51.1%
	500 - 1,000	194	29.1%
	1,000 - 1,500	75	11.3%
	1,500 - 2,000	41	6.2%
	above 2,000	16	2.4%
Monthly household income (USD)	0 - 1,000	75	11.3%
	1,000 - 2,000	197	29.6%
	2,000 - 3,000	158	23.7%
	3,000 - 4,500	107	16.1%
	4,500 - 6,000	57	8.6%
	6,000 - 8,000	24	3.6%
	8,000 - 10,000	11	1.7%
	above 10,000	37	5.6%
Occupation (industrial sectors)	Primary	2	0.3%
	Secondary	85	12.8%
	Tertiary	341	51.2%
	Students	207	31.1%
	Household/Others	31	4.7%
Car license	Y	431	64.7%
	N	234	35.3%

(2) Pattern Distribution

Looking at the pattern distribution in both region, it seems that most respondents could identify themselves with one of the ten patterns. We find that only 2% of the respondent answered “none of above patterns fit to my experiences” (see **Table 3**). Pattern 8 receives the biggest share whose verbal description is “basically I prefer HSR for my inter-city travel since I started using it”. This pattern represents 21% of our survey respondents and these people can be classified as “fast adopters”. We remind that we filter those who answer that they do not use HSR, in other words the percentage shown in **Table 3** do not show population usage percentages. We find that only 1.2% answer that they have never used HSR which is clearly lower than the actual percentage of population who never used HSR. This is though not surprising given that the survey title will have attracted also mostly HSR users.

25.6% of our sample, that is those choosing pattern 3 or 5, can be classified as low HSR usage travelers. We note that these 2 patterns have higher proportions in Taiwan. Another difference between Taiwan and Shanghai is pattern 10. We included this pattern considering specifically the HSR accident in 2011 in mainland China. The public safety concerns may have decreased the HSR demand for a period of time, but users might have restarted taking HSR after some time passed. The distribution indeed shows a higher portion of travelers from China who chose pattern 10.

Table 3 HSR Usage Pattern Distribution

Pattern	Taiwan		Shanghai		Total	
	No.	%	No.	%	No.	%
1	34	10.5	51	11.8	85	11.3
2	28	8.6	24	5.6	52	6.9
3	53	16.4	53	12.3	106	14.0
4	13	4.0	59	13.7	72	9.5
5	58	17.9	37	8.6	95	12.6
6	15	4.6	21	4.9	36	4.8
7	21	6.5	25	5.8	46	6.1
8	66	20.4	95	22.0	161	21.3
9	15	4.6	25	5.8	40	5.3
10	15	4.6	34	7.9	49	6.5
None of above	6	1.9%	7	1.6%	13	1.7
Total sample	324		431		755	
Valid sample	309		384		693	

(3) Grouping into Aggregate Patterns

In the initial data processing, we analyze the behavioral characteristics among HSR usage pattern. Though 10 usage patterns were chosen by respondents, to simplify, we grouped these original patterns into four groups of travelers by the speed of adaption process according to its description and usage pattern, namely: fast adopters, slow adopters, those who once adopted but dropped usage at some point (dropped group), and non-adopters. Unanswered/skipped questions and those answered usage pattern as "none of above", were excluded, 655 valid samples were validated in descriptive analysis and will be applied in MNL analysis in **section 5**, detailed pattern grouping see **Table 4**.

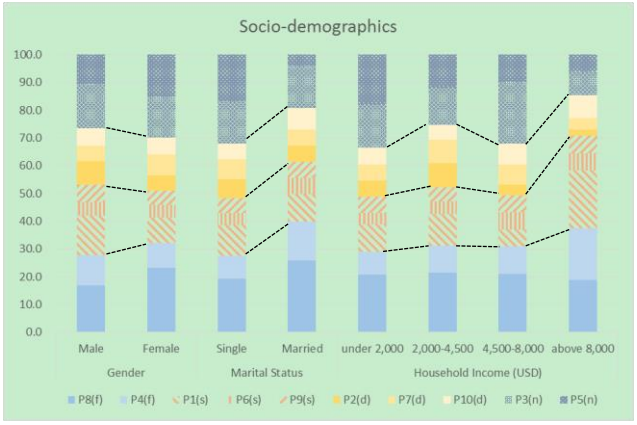
Table 4 Aggregate Patterns

Groups (pattern No.)	Samples	%
fast (4,8)	201	30.7%
slow (1,6,9)	138	21.1%
adopted but dropped (2,7,10)	128	19.5%
non (3,5)	188	28.7%
Total	655	100.0%

(4) Distribution of Patterns among Socio-demographic Groups

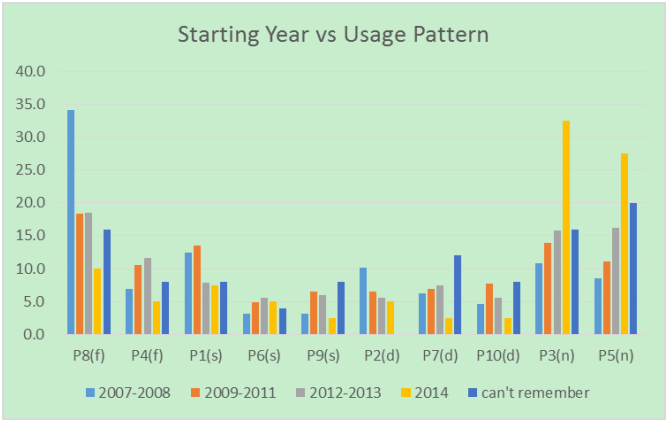
Regarding the aggregate pattern and the socio-demographics, we find that female are more likely to become fast adopter than male, and less likely to become slow adopter than male (see **Fig. 4**). As expected, we find less non-adopter from higher household income which would positively influence the affordability of higher HSR usage, comprised by HSR adopters (either fast or slow adopters). Similarly, marital status generally correlated with age and income, implies the changes in life course events and wealth status. Married travelers adapted faster to HSR than those who are single.

We asked the respondent for the year when they started to use HSR in usage recall questions. By comparing to the usage pattern distribution, we find nearly 35% of the travlers who started HSR in 2007 or 2008, describe pattern 8, "Basically I prefer HSR for my inter-city travel since I started using it.", as their HSR usage (see **Fig. 5**). On the other hand, those who just begun HSR trip in 2014, 60% of the travelers choose "non-adopter" pattern as their HSR usage. The significant difference suggest adaptation process might be time-homogeneous, where long term travel behavior invloves with varies of factors that influence one's adaptation, an early start in HSR seems more likely to adapt to the new travel mode.



Note: (f) denote as fast adopters, (s) slower adopters, (d) dropped at some point, (n) non-adopters.

Fig. 4 Socio-demographics and usage pattern.



Note: (f) denote as fast adopters, (s) slower adopters, (d) dropped at some point, (n) non-adopters.

Fig. 5 Starting year and pattern distribution.

(5) Comparison of Patterns with Usage Frequency

In order to examine how actual HSR usage projected to the proposed graphical usage pattern, actual usage frequency were obtained from recall questions and calculated into average frequency by pattern respectively. For better visualization to distinguish different characteristics among patterns, aggregate groups defined in section 4.3 are displayed in the same plot in **Fig. 6**. The non-adopter groups are found to have lower usage frequency compare to other patterns over times, where the average usage in 2014 is between one single trip/round trips. Moreover, in line with our descriptions and proposed pattern figures, pattern 3 are slightly higher than pattern 5 regarding the usage and description on attitudes towards HSR. The dropped group has distinguished usage drop at different time point, the result shows that the usage is in consistency with pattern and descriptions; where pattern 2 has a higher usage fre-

quency at the beginning, pattern 7 has higher usage at a certain period of time but recently reduced their usage. Though pattern 10 did not show the drop from actual usage at any time point, but the trend is similar to pattern 7 at early stage and appears the second increase on usage. Slow adopter groups are found to have a lower usage at the beginning compares to fast adopters, but end up with similar frequency, has explained the difference of time duration for individual adapting to HSR. Among slow adopter group, pattern 9 is much lower but end up with high usage frequency as pattern 1. We also find that pattern 6 has higher usage in recent years, where it described recent usage as "a regular pattern depends on certain reasons", compare to a fairly stable usage in pattern 1. The descriptions of the cyclic usage, to some extent, explained the slightly difference in usage trends, which possibly suggests it was conducted by greater number of HSR trips than those perceived usage as fairly constant over time. For fast adopter group, the parallel trend indicated the level degree of adaptation between pattern 8 and pattern 4. From the comparison of average frequency usage and pattern with description, the frequency trends were very similar to our proposed usage pattern, but with less information on the gradual changes over time and were generally difficult to obtain.

usage pattern. Though 10 usage patterns were chosen by respondents, to simplify, we grouped these original patterns into four groups of travelers by the speed of adaption process according to its descriptions and pattern figure as discussed in **section 4.3** and **Table 4**.

(2) Preprocessing of Explanatory Variables

On the other hand, as the survey is quite complex with combination of different perspectives, correlation among patterns might occurred, and sets of question may be omitted due to pattern they chosen; pre-processing procedure would help us to covert the observed parameters into fewer index variables and disclose some features from HSR travelers. Another analysis was proposed to examine reasons for gradual changes, particularly on the attitudes of respondent rating items over their assigned section.

a) Principal Component Analysis (PCA)

In order to eliminate the correlations among innovativeness scale items, principal component analysis (PCA) and Cronbach's alpha were well adopted from literature. We found the PCA results from our survey are in line with previous findings, where "creative original" and "willing to try" are specified from our data (see **Table 5**); however it also suggests that "willing to try" could be further be

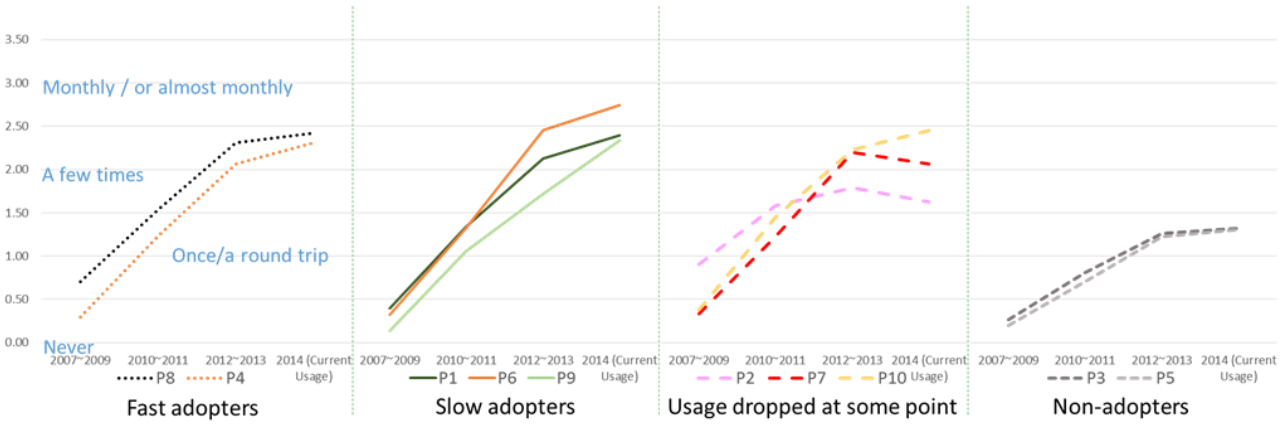


Fig. 6 Average HSR usage over time by usage pattern.

5. MNL ANALYSIS

(1) Aggregate Patterns (Dependent Variable)

Discrete choice models methodology provide an appropriate framework to capture behavior. Especially the Multi-nominal Logit model (MNL), has been the most widely used structure for modelling discrete choices in travel behavior (Ben-Akiva & Lerman[15], 1985). In the initial MNL model, we analyze the behavioral characteristics among HSR

distinguished into 2 components. From the item descriptions, we can verify the concept of "willing to try" can be further explained and defined as "observations from others or living experiences" and "personality" (separated by dashed line). The Cronbach's alpha test suggest to use creative original and observations from others or living experiences into further analysis to describe individual's psy-

chometric characteristics. As such, the innovativeness measures are broken down from 12 variables to 2 parameters in our further analysis.

Table 5 PCA and Cronbach's Alpha of the Innovativeness Scale

Factors	Innovativeness scale measurements	Component			Cronbach's Alpha
		1	2	3	
Creative Original	I am an inventive kind of person	.752			**0.831**
	I consider myself to be creative and original in my thinking and behaviour	.739			
	I enjoy trying out new ideas	.716	.225		
	I frequently improvise methods for solving a problem when an answer is not apparent	.713			
	I seek out new ways to do things	.700	.242	-.130	
	I am receptive to new ideas	.650		.151	
	I find it stimulating to be original in my thinking and behaviour	.579	.279	-.256	
Willing to try	I am reluctant about adopting new ways of doing things until I see them working for people around me	.133	.784	.189	**0.806**
	I tend to feel that the old way of living and doing things is the best way		.749		
	I am aware that I am usually one of the last people in my group to accept something new		.742		
	I rarely trust new ideas until I can see whether the vast majority of people around me accept them	.139	.673	.284	
	I must see other people using new innovations before I will consider them	.121	.638	.353	
	I often find myself skeptical of new ideas		.205	.664	
	I am suspicious of new inventions and new ways of thinking	-.347		.656	0.482
	I am generally cautious about accepting new ideas		.319	.614	

Note: Items with reversed scoring has converted into positive description

b) Trip Purpose and HSR Travel Time

In addition, trip purpose and HSR travel time may also influence traveler's usage during their adaptation process, as such, these factors were calibrated and taken into account for model estimation. From the previous descriptions in **section 3.3**, trip purpose over each time period were obtained from recall questions since the first time HSR usage. One could then easily identify HSR travelers, either to stick to the origin purpose from beginning, or had later utilized HSR as different purposes. We noted that some travelers have changed their trip purpose due to specific reasons from survey and therefore "Mixed-trip purpose" was defined and calibrated in order to examine whether this could be as one of the determines that effect the process of adaptation. The assumption here is that the meaning of "trip purpose changed" partly implies that HSR had become one of the choice set other than the trip purpose mostly dominated from the past/beginning usage. For example, traveler may conduct a number of business trips by HSR at the beginning, but later realized the convenience of long distance travel and therefore induced HSR usage for more leisure trips. For the rest of travelers who does not changed over time, were defined as single trip purpose and could be distinguished as commuters, business travelers, return-home travelers or leisure trip travelers.

HSR travel time could also be estimated from the question of "most frequently HSR OD stations" obtained from survey. HSR travel time was estimated and calibrated as dummy variables to control travel distance by following segments, travels within 1 hour, between 1~2 hours, 2~3 hours, and more than 3 hours. These segments could be regarded as short, medium, long, and ultra-long-haul distance travelers respectively. We also noted that in Taiwan, travel time are within 2 hours due to the island geometrics, therefore additional regional dummy variable was assigned to utility function for those travel time over 2 hours.

(3) MNL Model Results

Following the aggregated pattern groups, the non-adopters group (Patterns 3 & 5) was defined as reference group in the MNL analysis. The model is estimated using maximum likelihood in Python Biogeme, explicitly estimations and application are discussed in Bierlaire[16] (2003) and Bierlaire and Fetiarison[17] (2009). One of the advantages of Biogeme is the ability for parameter to be jointly estimate in the utility functions, where investigating common characteristics among groups now become feasible. MNL model was proposed in this section. The model analyzed the preprocessed variables including innovativeness factors, trip purpose, Section A items (motivations for start using HSR), and socio demographics, the year they started HSR usage as well as HSR travel time were investigated.

After several model iterations, the fast adopter group and dropped group are found to have a number of common variables that shares similar effects

compare to slow adopters group and non-adopters. One obvious reason is that "reason to drop" items were not taken into account in utility function, it would be very difficult for model to distinguish these 2 group. Nevertheless, the result may also implies that most of the dropped group could be originally came from fast adopters group, where slow adopters react slower in adaptation process and vice versa. The similar characteristics among fast adopters and once adopted but dropped group suggest that HSR operators should carefully examine the specific reason for travelers to drop from HSR.

To this end, we continue the estimation by combining the fast adopter group and dropped group as one group for better modelling performance. For brevity, final MNL result was shown in **Table 6**, sign of coefficient are in line with the previous MNL results. The first MNL result suggests that one's innovativeness of willingness to try has a positive influence on HSR usage. We also find, (though this is not self-evident), that the year when a respondent starts to use HSR is a significant determinant of the pattern, therefore the adaptation process does not seem to be time-homogeneous (note that this is not self-evident as the starting point in **Fig. 1** is "chosen" by the respondent).

Table 6 Trip purpose and Travel time impact on 3 Groups MNL

Trip purpose and HSR travel time				
Factors	Fast & Dropped	Slow adopters	Non-adopter	Descriptions
ASC	-2.58***	-2.42***	ref.	Alternative specific constant
WtT	0.506***		ref.	Perceptions perceived from others or living experiences
STA	-0.423***		ref.	Starting year of HSR
INCP	0.337***		ref.	Personal income
EDU	0.421***		ref.	Education degree
A02	0.260***		ref.	I expected it should be more comfortable than other travel options
A14	0.258***		ref.	Once the timetable improved I started using HSR.
A05	0.172**	ref.		I thought it is the safest travel option and therefore started using HSR.
A07	-0.146*	ref.		I was encouraged by my friends' / family's experience
A12	ref.	-0.221***	ref.	I wanted to work while travelling (working efficiently)
A11_SH	0.411***		ref.	Compared with other travel mode cost, HSR is more attractive (Shanghai v.)
MixTP	0.617***		ref.	Mix trips
TP_B_SH	0.512*	ref.		Business trip in Shnaghai
TP_L	ref.	-0.547**	ref.	Leisure trips
TP_C_SH	ref.	1.66**	ref.	Commuting trip in Shanghai
TT_1	0.208	ref.		HSR travel time within 1hr
TT_2	0.268*	ref.		HSR travel time between 1~2hr
TT_3	0.0993	ref.		HSR travel time between 2~3hr
Log_0	-692.126			
Final_log	-570.795			
ρ	0.175			
ρbar	0.148			

From the motivation items, the result further indicates that comfort (A02) and timetable improvement (A14) seems to be the most significant reason among HSR adopters to start using HSR. One of the factors distinguishes fast adopters and dropped group from others, is the perception of safety (A05): If one considered HSR to be a safe mode to travel, then that individual is more likely to become a fast adopter. Another factor though significant at 10% level, indicates that their decisions are less influenced by others (A07). Slow adopters, on the other hand, do not consider working while travel (A12) as the reason to start using HSR compared with other groups.

In terms of fare, the fare policy was quite different in both regions, where Taiwan has discount fare such as early birds and multiple-round ticket, HSR charge in China is based on a fixed rate. An interesting finding from here is that, for those who are currently adapted to HSR, that is, the fast/dropped and slow adopters; it was found that the discount ticket in Taiwan is not significant as the motivation to start using HSR. Instead, it's significant for Shanghai area though there's no fare campaign, but, HSR fare was considered as relatively attractive compare with other alternatives.

As for socio demographics, not surprisingly, higher education degree and personal income would encourage travelers adopting HSR compared to non-adopters. For the effect of trip purpose, it suggested that mix-trip has a very strong positive effect among HSR traveler, where the coefficient was estimated as 0.617.

On the other side, one who's HSR trips were mostly single trip purpose and never changed from their beginning HSR usage; leisure trips are found negative in slow adopter. HSR commuters in Shanghai, has a positive effect to become a slow

adopter. We argue that it might be a potential bias as commuting trip overs regular daily/weekly basis, it would be very difficult for one to recall as the mass trip generated by commuter, could easily erase previous detail travel information in memory. It may possibly misleads to an illusion of utilizing HSR for commuting trip from the beginning of one's HSR usage, but we acknowledge though that different arguments are also possible.

Dummy variables of travel distance (HSR travel time) were tested as well. It suggests that compare to other travel segments, HSR travelers who's most frequent journey within 1~2 hours would more likely to be fast adopters or dropped group. This is generally found as HSR short distance travel market would possibly existing a number of competitors such as buses, conventional trains, where HSR travel cost is considerable higher against other options. As for long haul trips, flight also become as a feasible option. The travel time indicators illustrate that a 2 hour HSR travel would cover a gap of market segment between air flights and other alternative options. In addition, business travelers in Shanghai turns out significant of 10% level as fast or dropped group in the model.

6. CONCLUSIONS AND ADVANCED MODELING APPROACH

(1) Conclusions

We suggest that asking users for their long-term travel behaviour with graphical patterns including questions on the reasons that lead to significant changes in usage might be one way to collect data that are otherwise difficult to obtain. Clearly such data is not fully accurate but, on the positive, might reflect the perceived usage pattern. Especially the missing detailed information on events likely to occur between the data collection points and triggered HSR usage changes. One might argue that these perceptions also drive the image of the transport mode in question and help to explain future decisions.

The proposed graphical pattern seems likely to capture most of usage pattern from travelers since, the respondent whom answered "none of above pattern fit to my experiences" is less than 2 % in China and Taiwan. However, the designed pattern must rely on pilot survey and modify descriptions and usage pattern according to feedbacks from target users. As we initiated a survey of 50 samples in both region earlier. Drawing together of graphical pattern with usage descriptions, it offers not only gradual usage changed from their past experience but also disclose detailed information on the different level of adaptation process towards HSR over time. This would enable researchers to focus on specific patterns and given the potential such as comparison study among pattern. For example, looking at pattern 1, 4, 6, and 8 would give a perfect example, though all these patterns requires section A, B and C to be answered, there might be some insight findings as we distinguish the different degree of adaptation, or the significance of "induced demand" generated by individuals.

The attitudinal factors were obtained in our survey and processed in principal component analysis. Innovativeness factors are brake down to 2 variables and in line with previous literature, but further suggest that "willing to try" could be divided as "observations from others or living experiences" and "personality".

The combined parameters from MNL result suggests that fast adopters and dropped group shared similar characteristics compared to slow adopters. This possibly indicates the drop group are once the fast adopters rather than slow adopters. Our first MNL results suggests that we can indeed distinguish and explain the behavior of some user groups, though we also acknowledge that our model fit is low. As expected, from the attitudinal factors, we find that one's perceptions of "willing to try" has a positive impact on a person's likelihood to start using HSR. As for socio demographics, not surprisingly, higher education degree and personal income would encourage travelers adopting HSR. For motivation items, comfort and timetable improvement are found to be the common reason to attract people for starting HSR trip. HSR operator should keep in mind that perception of safety is crucial for travelers adopt to HSR, the more perception of safety traveler perceived, the more likely to become a fast adopter.

The perspective of HSR adopters towards fare seems different across strait. HSR adopters in Taiwan doesn't consider the discount as the motivation to start HSR trip. Note that this should not over-interpreted as "discount wasn't attractive", but to emphasis that fare discount was not effective on those who had adapted to HSR in Taiwan. The Shanghai case illustrate HSR adopters are more price sensitive, which very much rely on the low cost fare controlled by railway authority; but we are also aware that unlike HSR competitors in Taiwan, only a few options are available for long-distance travel in China regarding with its geography.

Utilizing HSR on different trip purpose over time was found positive on HSR adopters. It entails that

HSR had become one of the choice set other than the trip purpose mostly dominated from the past/beginning usage. While we argued traveler who stick to commuting shown positive in slow adapter, might be bias due to the mass trips generated on frequently basis could possibly mislead the memory over time. Travel time further indicates the superiority feature of HSR, supplement the gap between flights and other travel modes. Medium distance HSR travelers adapt faster than other traveler.

(2) Advanced Modeling Approaches (current work)

Our objective in this study, is to discuss the usefulness and limitations of our approach, for obtaining HSR long term behavioral data over several years. Since cross-sectional or panel data is not feasible, we proposed a new methodology based on graphical pattern usage with corresponding items, investigates the gradual change of HSR usage over time. As we acknowledge that seeking an appropriate modeling approach for this data may be quite challenging. One major issue from our MNL analysis was the factors in sections B to D, were not considered in estimation. Including these items in MNL is though not possible as the questions were not answered by all respondents. One might formulate the problem though as a joined or nested choice model between one of the groups defined in **Table 4** and one of the 10 specific patterns which would then possibly allow including those questions, but came up to another issue of the limited alternative (pattern) specific variables from the survey. Alternatively, one might use Sections B to D to model the choice between specific patterns in a separate model, one possible approach, as our current work, is the discriminant analysis, as the usage pattern are known a priori. It could classify predictor variables and distinguish items that most effective on classification among the groups.

One might further and more generally have to discuss though the assumption of utility maximization for such models using long-term patterns in which decisions are likely to be conditional on previous decisions and other external factors. In other words: Do people choose patterns or do they happen to one? Partly as a way to avoid such questions, we therefore also consider more descriptive models such as explaining the observed changes in frequency with Markov chain models, a stochastic process to estimate transitions probabilities from one state of usage to another state, based on socio-demographics, innovativeness and possibly by extracting some "attitudes", such as price-sensitive or comfort-sensitive from the other questions.

APPENDIX A
INNOVATIVENESS MEASUREMENT

No.	R.E.	Items Descriptions	WtT	C.O.
1		I enjoy trying out new ideas		*
2		I seek out new ways to do things		*
3	*	I am generally cautious about accepting new ideas	*	
4		I frequently improvise methods for solving a problem when an answer is not apparent		*
5	*	I am suspicious of new inventions and new ways of thinking	*	
6	*	I rarely trust new ideas until I can see whether the vast majority of people around me accept them	*	
7		I consider myself to be creative and original in my thinking and behaviour		*
8	*	I am aware that I am usually one of the last people in my group to accept something new	*	
9		I am an inventive kind of person		*
10	*	I am reluctant about adopting new ways of doing things until I see them working for people around me	*	
11		I find it stimulating to be original in my thinking and behaviour		*
12	*	I tend to feel that the old way of living and doing things is the best way	*	
13	*	I must see other people using new innovations before I will consider them	*	
14		I am receptive to new ideas	*	*
15	*	I often find myself skeptical of new ideas	*	

Source: (Hurt, Joseph, & Cook, 1977)
Note: R.E.: "Reversed expression"; WtT: "Willing to try"; C.O.: "Creative original"

APPENDIX B
ITEMS IN SECTION A, B, C, AND D

Items descriptions (section A)	Mean	Std. Dev.	Im-portant	Most important	%
I expected HSR to be speedy and to save me time.	4.11	1.06	207	306	77.03
I expected it should be more comfortable than other travel options.	3.28	1.09	219	82	45.20
I thought it should be more reliable than other travel options.	2.98	1.15	162	67	34.38
I thought it is the safest travel option and therefore started using HSR.	2.89	1.17	151	59	31.53
I was curious about HSR, it sounded exciting and cool.	2.81	1.24	129	72	30.18
Once the timetable improved I started using HSR.	2.78	1.24	156	53	31.38
I was often stuck in traffic and therefore wanted to try HSR.	2.67	1.25	133	55	28.23
I was encouraged by my friends' / family's experience	2.57	1.22	125	44	25.38
A lot of positive feedbacks from media / internet encouraged me to try it out.	2.50	1.18	116	34	22.52
Only when the other modes / options became worse (e.g. flights) I started using HSR.	2.45	1.24	101	44	21.77
I wanted to work while travelling.	2.37	1.26	116	37	22.97
HSR had a sales campaign and the price was so attractive (TW)/ compare to the fare, HSR was more attractive than other modes (SH).	2.37	1.28	98	48	21.92
When accessing the HSR station became easier, I started using the service.	2.36	1.19	89	32	18.17
My company / organization sent me on a business trip.	2.27	1.39	70	74	21.62
I made a trip that I would not have done without HSR.	2.05	1.24	58	44	15.32

Items descriptions (section B)	Mean	Std. Dev.	Im-portant	Most im-portant	%
HSR had improved its access to the station, therefore I started using HSR more.	3.22	1.20	165	61	47.28
I was satisfied with my initial HSR experiences.	3.18	1.13	152	50	42.26
I realized HSR has a sales campaign and the price is so attractive (TW, 180 valid sample).	3.17	1.40	44	39	46.11
The frequency improved, making it feasible for me to travel more often.	2.91	1.24	114	51	34.52
I realised the service is better than I thought.	2.83	1.13	99	36	28.24
The other modes / options became worse (e.g. flights), so I used HSR more.	2.73	1.26	113	38	31.59
I was encouraged by my friends' / family's experience.	2.36	1.17	71	21	19.25
A lot of positive feedbacks from media / internet encouraged me to use the service more regularly.	2.25	1.13	51	20	14.88
I moved to another place.	2.17	1.34	52	42	19.67
I have changed my job / got a different job (including getting your 1st job).	2.15	1.34	60	39	20.71

Items descriptions (section C)	Mean	Std. Dev.	Im-portant	Most important	%
It's speedy, it has proven to save my time.	4.04	1.03	117	148	73.82
I feel comfortable when traveling with HSR.	3.47	1.12	126	65	53.20
I just got used to HSR.	3.36	1.18	108	67	48.75
I am satisfied with the service.	3.31	1.12	115	51	46.24
I regularly book discount ticket (TW, 135 valid sample).	3.21	1.40	30	33	46.67
Because I feel safe.	3.11	1.17	100	42	39.55
I now prefer HSR rather than driving cars.	3.01	1.33	96	50	40.67
My way of travel is decided by others and they keep using HSR.	2.73	1.26	71	34	29.25
My business now strongly depends on HSR.	2.63	1.29	65	33	27.30
I simply have to though I don’t like it.	2.08	1.16	33	16	13.65

Items descriptions (section D)	Mean	Std. Dev.	Im-portant	Most important	%
The fare has become too expensive for me.	3.00	1.43	44	45	39.21
I only used HSR when there's a discount, otherwise HSR wouldn't be my preferred option (TW, 110 valid sample).	2.85	1.55	20	23	39.09
I have changed my job and now don't need HSR so much anymore.	2.23	1.41	27	24	22.47
I don't use HSR so much anymore since I moved to other places.	2.19	1.35	25	21	20.26
I now prefer other public transportation.	1.90	1.01	15	3	7.96
I now prefer to drive.	1.82	1.04	13	5	7.93
Access to the HSR station became worse.	1.80	1.07	17	5	9.69
I switched to other modes / options due to their improvement on its service.	1.77	0.98	12	2	6.17
The timetable changed and was not convenient for me anymore.	1.72	1.02	10	5	6.64
I heard a lot of negative feedback from media / internet discussion.	1.71	1.00	13	4	7.49
The service quality decreased (crowding, cleanness, and etc.)	1.61	0.86	8	1	3.96
I felt HSR wasn't safe.	1.58	0.91	9	3	5.31
It became unreliable.	1.56	0.93	10	4	6.17
My friend / family had some terrible experience on taking HSR.	1.49	0.80	3	2	2.20
In general, I am NOT satisfied with my previous HSR experiences.	1.47	0.83	6	2	3.52
I have had a particular terrible experience.	1.43	0.78	4	2	2.64

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