Accounting for the impact of variety-seeking: theory and application to HSR-air intermodality in China

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Abstract

While variety-seeking has been analysed intensively in consumer marketing, little is known about its impact in the transport world where many novel travel services have emerged in recent years. In this paper, we investigate how variety-seeking could influence intercity travellers' mode choice decisions in the new context of HSR (high-speed rail)-air intermodality in China. The study is based on data collected in Shanghai, including responses to stated choice tasks and attitudinal statements on variety-seeking. An integrated choice and latent variable (ICLV) model is proposed with a view to provide us with a more behaviourally realistic explanation of respondents' choice decisions. The research findings suggest that variety-seeking has different impacts across modes, where variety seekers would be more likely to choose the newly-introduced integrated HSR-air option whereas variety avoiders have a higher propensity to choose car-air or traditional separate HSR-air alternative. Meanwhile, this study also examines the impact of various level-of-service attributes in mode choice behaviour, with results implying that long layover would heavily impair the attractiveness of integrated HSR-air service, and integrated luggage handling service is favourable to attract intermodal passengers while the effect of integrated ticketing system remains ambiguous.

Keywords: HSR-air intermodality, stated choice, variety-seeking, mode choice, latent variable, discrete choice model

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1. Introduction

1.1. Research background

In recent years, a growing number of researchers and practitioners have moved away from merely analysing the competition between air and HSR (high-speed rail) to viewing the air-HSR relation from a perspective of inter-modality featuring cooperation and complementarity. The European Union has long been promoting the complementarity between the air network and the rail network (European Comission and Transport, 2011) out of capacity, environmental and financial concerns, with an aim to not only alleviate the congestion at busy airports, but also improve the efficiency of the transport system as a whole. In Europe, while rail links (e.g. conventional rail, light rail, metro) at airports can be found relatively widely, HSR-air integration is mainly operationalised in airports with direct connection to a HSR network which requires a large amount of infrastructure investment and operating costs (Maffii et al., 2012), among which key examples are the cooperation between Thalys trains and Paris Charles-de-Gaulle Airport as well as between Deutsche Bahn trains and Lufthansa Airline on the Stuttgart-Frankfurt route (Chiambaretto and Decker, 2012; European Commission, 2010).

China has established the world's largest HSR network, with over 22,000km in total by 2016 (Ministry of Transport of the People's Republic of China, 2017). An integrated HSR-air service, treating HSR travel as a feeder leg of long-distance air travel and allowing passengers to purchase HSR and flight services together, was first launched by China Eastern Airline in conjunction with the Shanghai Railway Bureau in 2011. HSR-air intermodality emerged in China mainly out of two different reasons. Firstly, HSR-air intermodality is expected to facilitate passengers from non-airport regions to access nearby airports where they can travel to/from a distant place. For example, passengers from many prefecture-level or county-level cities in the Yangtze river delta region can have access to airports in Shanghai through HSR. Secondly, HSR-air intermodality is considered capable of diverting passengers to/from a crowded hub airport to a nearby airport in order to decongest the busy hub airport. For example, passengers to/from Beijing Capital Airport - one of the world's busiest airport - are given the options to use the nearby Tianjin Binhai Airport and Shijiazhuang Zhengding Airport, which are about 150km and 300km away.

1.2. Research questions

Although more cities begin to participate in HSR-air intermodality in China, the general public are not familiar with the integrated service as reflected by its relatively low passenger flow. Take Shanghai as an example, in 2015, about 8100 passengers chose China Eastern Airline's integrated HSR-air service which requires transferring at Shanghai (either HSR travel first or air travel first) every month while the monthly average volume of flight passengers, including both inbound and outbound, of two Shanghai airports is 8.27 million. The limited passenger demand might be potentially due to the relatively low level of integration of the current HSR-air intermodal service. To be specific, HSR-air intermodality products in China usually simply increase the time-window between the HSR segment and the air segment to diminish the possibility of fail-on-board due to service delay on either segment, making it less attractive to passengers (Li and Sheng, 2016). Besides, although passengers no longer need to purchase tickets twice for HSR journey and air journey, they are only offered with limited options in terms of airline, departure time, etc., and they are still required to collect train ticket and flight ticket separately. Moreover, as pointed out by a study on China's HSR-air intermodality (Givoni and Chen, 2017), though the benefit of realising integration between air and HSR has been recognised by China's policy makers and the integration infrastructure has been implemented in Shanghai, the actual integration level of the service is low, which can be attributed to 'the institutional (and cultural) division between air and rail transport and excessive importance attached to the competition between air and rail'.

This suggests that the underlying benefits of HSR-air intermodality in China are still yet to be justified and explored, and also reveals the necessity to analyse passengers' preferences towards different level-of-service attributes of the HSR-air intermodality and to examine how they affect passengers' mode choice in the context of HSR-air intermodality. In particular, unlike traditional mode choice studies which treat each mono-mode as an alternative in choice set, transport planners need to examine how passengers would choose among several multi-modes alternatives where direct travel service between the origin and destination is unavailable.

Apart from observable level-of-service attributes, other unobserved factors might also influence passengers' mode choice behaviour. For example, Bennett et al. (1957) suggested that perception of some emotional experience may affect passengers' mode choice, such that air travel is considered to be associated with anxiety, while rail travel is associated with feelings like slowness, etc. In the current paper, we particularly examine the impact of the underlying variety-seeking tendency on mode choice behaviour in the new context of HSR-air intermodality. That the integrated HSR-air service could still be treated as a new option in the intercity market even though it has been in the market for around six years, is largely due to the unfamiliarity with the HSR-air intermodality of the general public in China as well as the relatively low integration level of the integrated HSR-air service at the moment. We conduct variety-seeking analysis with a view to explore whether variety seekers would have a higher propensity to choose the new integrated HSR-air alternative while variety avoiders would be more prone to stick to other long-existing traditional alternatives, such as car-air and air-air and separated HSR-air. It should be noted that this paper only addresses such short-run impact of variety-seeking, therefore neither the mode choice behaviour in the long term after the market becomes fully mature, nor the link between choice preference variability/stability and variety-seeking in stated-preference survey is discussed. To be specific, we explore the measurement of underlying variety-seeking and incorporate such information to the choice model in different ways to enhance the behavioural explanatory power of the model.

The main methodology utilised is an ICLV (integrated choice and latent variable) model based on the framework proposed by Ben-Akiva et al. (2002) as it has become the standard approach to understand the impact of unobserved factors on people's decision-making. Our ICLV model has a random utility by the maximisation (RUM) kernel, where the utilities for the different modes are influenced not just by observable characteristics but also the latent construct of variety-seeking which is also used to explain the responses to a series of attitudinal statements.

In the remaining of the current paper, there are five sections. The next section summarises the studies of relevant literature, which is followed by a section that describes the experiment design and data collection work. The applied methodologies and model specifications are presented in section 4. Then in section 5, the estimation results are discussed. In the end, the conclusions drawn in the current research and the shortcomings and research potentials are summarised in section 6.

2. Literature review and research contribution

2.1. HSR-air intermodality analysis

Among the research into HSR-air intermodality, most of the studies focus on estimating the impact of initiating HSR-air intermodality on, for example, environmental benefits, fares, traffic volume and welfare (Albalate et al., 2015; Dobruszkes and Givoni, 2013; Jiang and Zhang, 2014; Xia and Zhang, 2016; Zanin et al., 2012; Jiang et al., 2017). Other studies identify factors that affect the service level of HSR-air intermodality, such as travel time, travel price, ease of transfer, ease of access/egress, baggage handling system, ticket integration, service reliability, check-in and security-check procedures (Costa, 2012; Vespermann and Wald, 2011). An earlier survey by the International Air Transport Association (2003) suggested that poor connection was considered by passengers as the main barrier to travel by HSR before or after flying.

However, analysis of mode choice behaviour is rather limited, among which the majority can be found in the Spanish context (Brida et al., 2017; Martín and Román, 2013; Román and Martín, 2014). The work of Román and Martín (2014) was based on a stated-choice survey which confronted passengers with choices between air-air alternative and the integrated HSR-air alternative if they needed to travel between the remote Island of Gran Canaria and different cities in mainland Spain. It illustrates through various discrete choice models that different travel time components (connection time in particular) and fare integration are highly valued by passengers while the impact of luggage integration is important only for individuals who check in luggage and travel for leisure purposes.

The first and the only comparable analysis conducted in China is by Li and Sheng (2016) which examined mode choice behaviour and made travel demand forecasts on the Beijing-Guangzhou corridor. Notwithstanding the enlightening and valuable findings, some shortcomings of this research can be identified: 1) attribute levels were fixed and respondents from a same group were faced with one same choice task, which might lead to the weakness of examining the trade-off between different attributes and the potential inaccuracy in modal share forecasting; 2) the choice scenario was specified as choosing from a choice set consisting of direct flight, direct HSR, and integrated HSR-air for a domestic intercity travel, whereas we argue that the trade-off between travel time and travel cost would dominate decision-making in such a scenario, making it difficult to detect the roles of other level of service attributes; 3) the authors acknowledged in that paper the necessity to analyse the impact of travel time reliability due to delay, but did not considered it to avoid survey complexity. Other attributes closely related to integration (e.g. luggage integration, ticket integration) were not accounted for in that paper as they were treated as being unimportant in passengers' decision-making, however our research results demonstrate that this is not necessarily the case. Since national and local governments in China are now putting even more effort to establish integrated HSR-air service in more cities, it is of vital importance to have a greater in-depth understanding on how travellers' mode choice behaviour is influenced by various level of service attributes in order to improve and better benefit from the integrated HSR-air service. In this regard, this paper differentiates itself from Li and Sheng (2016) by accommodating the shortcomings mentioned above and adopting more flexible and advanced discrete choice models.

2.2. Variety-seeking analysis

The notion of variety-seeking comes from research in consumer marketing, where McAlister and Pessemier (1982) first made a comprehensive review on variety-seeking behaviour. Variety-seeking can denote different phenomena. For example, some research treats variety-seeking as the phenomenon of 'an individual choosing a different alternative from his or her choice set over time due to the induction of the utility (s)he derives from the change itself, irrespective of the alternative (s)he switches to or from' (Borgers et al., 1989; Givon, 1984). That is to say the variety-seeking behaviour is more intrinsically motivated rather than extrinsically derived (Van Trijp et al., 1996). In a recent study of variety-seeking on restaurant choices by Ha and Jang (2013), it is stated that variety-seeking can be defined as an intention to either vary among familiar alternatives (alternation) or to choose a new alternative (novelty seeking) - the current paper is based on the latter.

Variety-seeking has been intensively analysed in consumer marketing and commonly observed in actual data in real life, showing that variety seekers tend to seek diversity and new experiences. Adamowicz (1994) and Borgers et al. (1989) established different dynamic models to measure variety-seeking and accounted for them in recreational site choice behaviour, both using longitudinal data and incorporating previous experience to reflect the role of habit and variety-seeking. Empirical studies on brand switching behaviour demonstrate that the ability to measure consumers' variety-seeking in a certain product market will bring about a better understanding of brand switching in the market (Givon, 1984; Van Trijp et al., 1996). It is further concluded by Legohrel et al. (2015), who applied a chi-squared automatic interaction detection (CHAID) segmentation approach to analyse international travellers' choices of hotels and restaurants, that variety-seeking could be treated as a tool to segment markets and different variety-seeking behaviours require different marketing strategies.

Research into variety-seeking is much more limited in the transport literature. Earlier attempts can be found in Schüssler and Axhausen (2011) and Rieser-Schüssler and Axhausen (2012) on mode choice between car and public transport based on daily travel diary data and self-developed scales, in which variety-seeking was accommodated as a latent variable. Other relevant research includes studies of the impact of inertia on adopting the new alternative which requires a combination of revealed-preference (RP) and stated-preference (SP) data or launching SP surveys twice, i.e. before and after the implementation of the novel facility/ service (González et al., 2017; Jensen et al., 2013). It has also been suggested that intrinsic personal preference might be a driving factor of choosing a specific alternative (International Air Transport Association, 2003), and that habit could act as a barrier to the change in mode choice bahviour and breaking old habits can potentially result in mode shift (Blainey et al., 2012; Thøgersen, 2006).

2.3. Research contribution

The current paper contributes to the literature in two different aspects. Firstly, it provides more evidence on mode choice behaviour analysis in the context of HSR-air intermodality in China through discrete choice methods. This could deepen policy makers' understanding of the driving factors behind passengers' mode choice and preference heterogeneity across passengers, resulting in higher capability of satisfying customers' needs and improving the integrated service. Secondly, this study extends researchers' knowledge of variety-seeking in the transport realm. This could assist policy makers to better identify potential consumers of the integrated HSR-air service as well as to improve marketing segmentation strategies by drawing upon information of variety-seeking rather than purely relying on the socioeconomic characteristics of passengers alone, and moreover, this analysis could offer insights to the investigation of variety-seeking's impact when other new transport service comes into play in this changing world where innovations keep emerging in recent years (e.g. sharing bicycle, sharing vehicle, automated vehicle).

Our results show that:

1. Different level-of-service attributes impose different impacts on utility function, that value of minor time differs between modes and between travel purposes, connection time between HSR network and aircraft network is highly valued by passengers, delay protection is more welcomed by passengers who are less familiar with the transfer city, the benefit of integrated ticketing system is perceived ambiguously whereas integrated luggage handling system shows attractiveness to passengers, especially those who travel with more than one piece of check-in luggage.
2. Variety-seeking can be manifested by a series of attitudinal indicators and its tendency varies across respondents.
3. Variety-seeking could explain part of the random taste heterogeneity across respondents, apart from the other random taste heterogeneity irrelevant from the latent variable.
4. The impact of variety-seeking on utility differs across alternatives, and people who possess higher (lower) level of variety-seeking tendency, can derive less (more) utility from car-air alternative and traditional separated HSR-air alternative, meanwhile more (less) utility from both air-air alternative and the new integrated HSR-air alternative.
5. Younger people and people with higher income tend to be more willing to seek variety.

3. Data

3.1. Regional context

The case study is based on data collected in Shanghai, an important city for both the air network and the HSR network in China. Shanghai has two airports which enjoy large catchment area in the Yangtze River Delta region and it currently takes around 1.5h to travel between them by metro. Hongqiao International Airport mainly provides domestic routes and some short-distance international routes (e.g. to Tokyo/ Seoul). Hongqiao HSR station, which is one of the largest railway station in Asia and the linkage of many HSR lines, enjoys a seamless transfer with Hongqiao International Airport[1], and constitutes the Hongqiao Integrated Transport Hub (the Hongqiao

[1]Passengers can walk through a passage linking Hongqiao HSR station and T2 terminal which provides domestic flights, and can take a metro train for one stop to move between

Hub) with Hongqiao International Airport. Pudong International Airport offers much more international routes and wider airline choices; moreover, it is positioned as an International gateway hub that serves a high percentage of transfer passengers and wide catchment area, the capacity of which will continue to be expanded. For example, the recently initiated Pudong International Airport Phase III Expansion Project, involving the construction of an additional satellite concourse facility which will be connected to the existing T1 and T2 terminals, is expected to be completed by 2019 and will support 38 million passengers annually[2]. In addition, according to the Shanghai-Nantong Railway Phase II Plan, a new railway station will be established at Pudong International Airport, which will enable Pudong International Airport to be connected to the HSR network by linking it with the trunk HSR line through a new branch line, thus contributing to the establishment of Pudong Hub in the future.

Although seamless intermodal transfer only takes place at Hongqiao Hub at the moment, a pilot survey at Hongqiao Airport showed a very low rate of successfully approaching transfer passengers, especially cross-border passengers, whom we regard as the main target of integrated HSR-air service. On the contrary, Pudong Interndational Airport can guarantee a much higher probability of intersecting cross-border transfer passengers, who are more capable of interpreting the concept of integrated HSR-air service and the survey tasks. Therefore we carried out the final survey at Pudong International Airport. In addition, since Pudong International Airport would in the near future evolve into an intermodal hub, it is necessary to understand passengers' perception of intermodal service and their preference towards various level-of-service attributes, such that the results could provide insights to policy makers and transport planners who have interests in promoting the establishment of Pudong Hub. Since we rely on a stated choice survey, in which the choices are actually hypothetical, we are able to look at non-existing modes even when seamless transfer between air and HSR is currently unavailable at Pudong airport. This also makes it possible to examine the impact of different levels of transfer ease (e.g. seamless transfer within Hongqiao or Pudong Hub, transfer between Hongqiao and Pudong)

Hongqiao HSR train station and the T1 terminal which focuses on international flights at the moment.

[2]See Wikipedia. https://en.wikipedia.org/wiki/Shanghai_Pudong_International_Airport

on passengers' mode choice behaviour.

3.2. Definition

Based on the definition of passenger intermodality given by the European Commission's Directorate-General for Mobility and Transport (2010), we define HSR-air intermodality as the situation where air and HSR provide an integrated service as one combined journey with a fast and even seamless transfer. It is in detail described in our case study as a situation where: 1) a passenger is travelling from a nearby domestic origin O to an overseas destination D; 2) direct flights from O to D are unavailable; 3) a passenger from O to D needs to travel via Shanghai; and 4) a passenger can only travel by air between Shanghai and D. We denote the first journey between O and Shanghai as the 'minor leg' on which various modes are available, and the second journey between Shanghai and D as the 'major leg' where air is the only option. Under such a scenario, HSR constitutes a substantial part of the journey, and serves as a feeder service to airlines on additional spokes from a hub airport, and mode substitution between air and HSR exists on the minor leg (Román and Martín, 2014; Xia and Zhang, 2016; Brida et al., 2017; Givoni and Banister, 2006).

The present study considers the choice scenario of the minor leg coming before the major leg rather than the other way around out of concern that if a passenger is delayed on the first leg, the consequence of missing a long-haul flight would be much more severe than missing a short-distance HSR train on the second leg, especially given the relatively high frequency and low price of HSR service in Shanghai and its catchment area.

3.3. Questionnaire and respondent sampling

A face-to-face survey was conducted at Pudong International Airport in January 2017. Passengers were approached at random and were then screened to ensure that the majority of them were passengers from/to regions in proximity to Shanghai, i.e. within a distance of 210min by HSR from Shanghai[3], and where aircraft service is available to Shanghai, such that respondents could have a good understanding of our choice scenarios.

[3]This threshold is chosen as all the cities served by HSR-air intermodality through Shanghai could reach Shanghai within 210min by HSR when authors designed the survey.

The survey was divided into five components, collecting data on: 1) current travel information, such as origin, destination, travel purpose and number of check-in luggage; 2) travel experience, such as the frequency of air/ HSR travel in the past two years; 3) responses to stated choice tasks; 4) responses to statements in self-designed scales; 5) socioeconomic characteristics of respondents, including gender, age, employment, education, income and nationality.

A final sample of 123 respondents was obtained. The dominant modes for the feeder journey of the current travel were air (45.1%) and HSR (30.8%), indicating the potential market for a well-developed integrated HSR-air service. Table 1 summarises the descriptive statistics of respondents. It can be observed that respondents were relatively evenly distributed between genders. The respondents tended to be young and highly educated. We did not control the proportion of respondents with different socioeconomic characteristics to make the data representative of the real world population, because our work is an exploratory study on exploring the impact of variety-seeking, and international travellers themselves are not representative of the Chinese population.

3.4. Stated choice component

The stated choice component presented respondents with 8 stated choice tasks, each with 4 alternatives, namely car-air, air-air, separated HSR-air and integrated HSR-air, giving a total of 984 choice observations for analysis. Car-air means using car on the minor leg and using flight on the major leg; air-air means connecting flights; separated HSR-air refers to the traditional connection which involves purchasing air and HSR tickets separately; integrated HSR-air refers to the new HSR-air intermodal service. Figure 1 gives an illustration of the stated choice scenario.

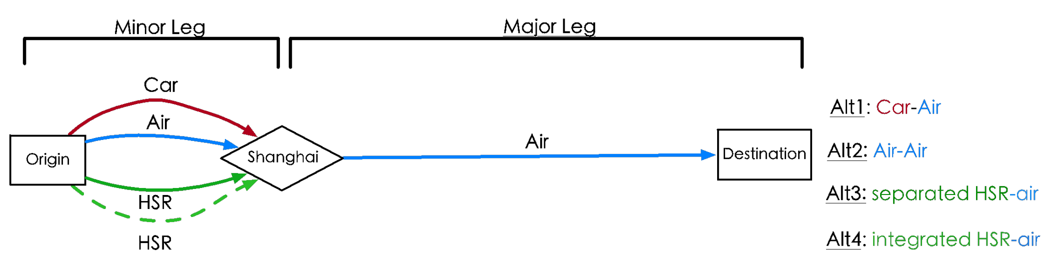

Figure 1: Illustration of choice scenarios in SC survey

Table 1: Descriptive statistics of the sample that completed the whole questionnaire

	Levels	***Sample (%) (N=123)***
Travel Purpose	Holiday travel	44
	Family visit	15
	Business travel	15
	Study in another city	22
	Others	6
Check-in Luggage	0 (none)	11
	1 (one)	59
	2 (more than one)	30
Familiarity with Shanghai city	0 (not at all)	28
	1 (general)	35
	2 (very well)	37
Gender	Female	55
	Male	45
Age	<23	31
	23-35	47
	36-45	14
	46-60	7
	>60	1
Education	Elementary level or below	1
	Secondary level	3
	Graduated from technical school	6
	Bachelor degree (Obtained/ in the course)	64
	Master degree or above (Obtained/ in the course)	26
Annual income[a] (CNY)	<50,000	39
	50,000-100,000	15
	100,000-150,000	17
	150,000-200,000	15
	200,000-250,000	3
	>250,000	11
Employment	Student	38
	Work for government department or institutions	10
	Work for company	28
	Self-employed	11
	Freelancer	2
	Retired/ unemployed	1
	Others	9

[a]CNY/USD≈0.145 during survey period.

Our choice scenario differentiates itself from that specified in Li and Sheng (2016), by excluding direct travel options in the choice set, as we argue that trade-offs between travel time and travel cost would dominate decision-making strategy otherwise. In addition, unlike the choice set in Román and Martín (2014), we herein split the 'HSR-air' alternative into a separated one and an integrated one. Since the Yangtze River Delta region has a very dense HSR network, many passengers currently buy tickets separately when they need to take a HSR train to reach the airport. Thus there would be a choice between the traditional separated HSR-air and the new integrated HSR-air when both options are available.

Stated choice tasks were generated in Ngene (Metrics, 2012) using a D-efficient experimental design (Rose and Bliemer, 2007) which drew prior information from a pilot survey conducted in July 2016 at Hongqiao International Airport. Two separate experimental designs, each with 5 blocks, were produced in order to account for the different distance (i.e. short/ long) on the major leg (and the resulting lower/higher travel cost) while maintaining the available levels of all the other attributes the same in the two designs. Stated choice tasks were presented to respondents in a randomised order to minimise the order effect. A total of 7 attributes were used, not all of which apply to every alternative. The full list consists of travel time on the minor leg, transfer time, connection time, protection in case of delay on the minor leg, ticket integration, security check and luggage integration, and travel cost[4]. Travel time on the major leg was not considered in the survey as it would not vary across choice tasks and alternatives.

The sum of transfer time and connection time gives the time intervals between the departure time of the major leg and the arrival time of the minor leg (i.e. layover). Transfer time refers to the moving time between the two legs which in particular takes a value of 0min for a seamless transfer at an intermodal hub; it can also take a value of 90min or 45min, both indicating a movement between two airports, with the former corresponding to the current transfer time by metro and the latter to the reduced transfer time should the potential rapid linkage between Hongqiao Hub and Pudong International Airport is established in the future. Transfer time is fixed at

[4]For the sake of brevity, the attribute of 'travel time on the minor leg' is called as 'minor time' for short, the attribute of 'protection in case of delay on the minor leg' is shortened as 'delay protection', the attribute of 'security check and luggage integration' is referred to as 'luggage integration' in the remain of this paper.

0min for car in order to reflect its capability of providing door-to-door travel, while it can take a value of 0min as well as other values for any of the other alternatives. It should be noted that when transfer time takes 0min, it refers to a very easy and seamless transfer between the minor leg and the major leg without the need to move between different airports/stations, rather than literally implying instantaneous movement between the two journeys. Besides, although parking availability may affect the actual transfer time, we do not explicitly specify it as its average impact can actually be captured by the alternative-specific constant in our model.

Connection time refers to the time spent on waiting and going through procedures (e.g. check-in, security check), which is fixed to the minimum pre-departure arrival time of 90min for the car-air alternative to reflect the high mobility of accessing the airport by car. Connection time can take five levels for each of the other three alternatives, where the minimum levels are all set to 90min in order to account for the minimum connection time for connecting flights regulated by airlines and the airport. Connection time can take a maximum of 420min/210min/330min for the air-air/separated HSR-air/integrated HSR-air alternative respectively, all of which are determined to ensure the attribute levels for connection time vary within reasonable ranges which can on the one hand allow for adequate variation of attribute levels which is necessary for estimating the attribute's sensitivity, and on the other hand ensure the viability of attribute levels presented to passengers in the stated choice survey[5].

Delay protection gives information on how the respondent would be compensated in case that the delay on the minor leg results in missing the flight on the major leg. There are three possible levels for this attribute, which are 'no compensation', '50% off on changing flight', and 'free flight change', where the 'no compensation' level always applies for the car-air and separated air-HSR alternatives.

Ticket integration describes the integration level of air and HSR ticketing systems, with four different levels, which are 'book tickets separately + fixed-time train on the minor leg', 'book tickets together without easy collection + fixed-time train on the minor leg', 'book tickets together with easy collection + fixed-time train on the minor leg', and 'book tickets together with easy

[5]Currently, layover can be as long as over 10h even at an intermodal hub. Thus we tried to achieve a balance between reflecting the reality and ensuring survey efficiency.

collection + flexible-time train on the minor leg'. What we mean by 'easy collection' here is that a passenger only needs to collect tickets one time while 'without easy collection' means that a passenger has to collect the ticket for the minor leg and for the major leg separately. Currently, the intermodal HSR-air service frees passengers from booking tickets twice but still requires them to collect the HSR ticket first at train station and then get the boarding pass at the airport, i.e. without easy collection.

Luggage integration refers to how many security checks and luggage check-in are required throughout the travel, with three different levels, which are 'no luggage handling integration system + two security checks', 'integrated luggage handling system available + two security checks', and 'integrated luggage handling system + one security check'. Herein, integrated luggage handling system allows passengers to check in luggage at the origin and collect luggage at the final destination; two security checks infers that both minor and major legs require security checks while one security check means that a security check is only required at the origin. The attributes of ticket integration and luggage integration do not apply for car-air alternative and are kept at the lowest level for separated air-HSR alternative. Figure 2 gives an example of stated choice tasks with the items in italic being held invariant over tasks.

3.5. Attitudinal statements

Attitudinal statements were used to measure variety-seeking. All statements were recorded in the form of a 7-point Likert scale, ranging from 1 being 'strongly disagree' to 7 referring to 'strongly agree'. The statements in the formal survey were refined through two pilot surveys as described below.

A pool of 67 initial statements were selected from various literature on variety-seeking, novelty-seeking, personality constructs, risk-taking, exploratory behaviour, arousal seeking and sensation seeking (Baumgartner and Steenkamp, 1996; Hoyle et al., 2002; Raju, 1980; Van Trijp et al., 1996; Van Trijp and Steenkamp, 1992; Weber et al., 2002). An sample of 30 respondents with a transport or psychology background were asked to score them and provide feedback when finished. Statements were then narrowed down to 33 and tailored to the Chinese transport setting, with the inclusion of new items developed by Oreg (2003).

The shortened questionnaire was then generated on the platform of Qualtrics and spread by online link through the Chinese social media app called WeChat. This link was publically accessible, and the respondents were mainly from the

	Car-air	Air-air	Separated HSR-air	Integrated HSR-air
Travel cost	¥1,250	¥1,050	¥1,150	¥1,250
Minor time	5h	1.5h	2.5h	2.5h
Transfer time	*0h*	0h	1.5h	1.5h
Connection time	*1.5h*	4h	1.5h	2.5h
Delay protection	*None*	Free flight change	*None*	50% discount on changing flight
Ticket integration	-	• *Book together* • *Fixed-time flight on minor leg* • *Easy collection*	• *Book separately* • *Fixed-time train on minor leg* • *No easy collection*	• Book together • Fixed-time train on minor leg • Easy collection
Security check and luggage integration	-	• Two security checks • No integrated luggage handling system	• *Two security checks* • *No integrated luggage handling system*	• One security check • Integrated luggage handling system available

Figure 2: Example of the stated choice task in the questionnaire

Yangtze River Delta Region. This second pilot survey was carried out during November 25-27, 2016, yielding 234 complete responses. Three factors were extracted by factor analysis in SPSS, which could be interpreted as 'resistance to change', 'need for variety', and 'need for information'. Item analysis on each derived factor was conducted subsequently, resulting in 15 selected statements. The Cronbach's Alphas for the three factors are all above 0.6 (i.e. resistance to change: 0.639, need for variety: 0.701, need for information: 0.614), and each statement has an item-total correlation score between 0.2 and 0.8, which means that the statements are reliable to measure the three factors (Kline, 2015). While the insights from this factor analysis were used in the development of our choice models reported later in this paper, it should be noted that the specification of the latent variables should not be a priori expected to be the same as these factors given that the hybrid model also explains the choices made in the survey.

In the final survey, each respondent was required to score the attitudinal statements of resistance to change and need for variety in Table 2, of which A1-A6 related to need for variety and A7-A11 to resistance to change. It is easy to notice that either stronger agreement with statements A1-A6 or stronger disagreement with statements A7-A11 is associated with stronger variety-seeking tendency. Regarding this, statements A1-A6 and statements A7-A11 actually measure the same construct, i.e. *variety-seeking tendency*, from opposite ways. Responses to attitudinal statements are shown in Figure 3, where the extreme levels such as 1 'strongly disagree' and 7 'strongly agree' were much less frequently chosen than the others.

4. Methodology

In our work, we estimate three types of models which to different extents account for heterogeneity across respondents and the role of variety-seeking in mode choice behaviour in the context of HSR-air intermodality.

4.1. Multinomial logit model (MNL)

We first develop a MNL model as the base model (McFadden et al., 1973), in which U_{int} represents the utility obtained from alternative i in choice task t for respondent n. U_{int} consists of a deterministic portion V_{int} which is specified to be linear in parameters with an alternative-specific constant (ASC) δ_i, and an unobserved error term ε_{int} which is independently and identically distributed following a type I extreme value distribution. With J alternatives in each choice set, one δ is fixed to 0 for normalisation while the rest $J-1$ alternative-specific constants need to be estimated. With this, x_{int} is a vector of explanatory variables that represent the attributes shown to respondent n in choice task t for alternative i. Meanwhile, β is a vector that describes the estimated taste coefficients for these attributes. Finally, Z_n represents a vector of socioeconomic characteristics which is individual specific, and ω_i measures their impacts on utility functions, which differs across alternatives. The utility function can thus be written as:

$$U_{int} = V_{int} + \varepsilon_{int} = \delta_i + \beta' x_{int} + \omega_i' Z_n + \varepsilon_{int} \tag{1}$$

The probability of alternative i being chosen out of J alternatives by respondent n in choice situation t is then given by:

$$P_{int} = \frac{e^{V_{int}}}{\sum_{j=1}^{J} e^{V_{jnt}}} \tag{2}$$

Table 2: Attitudinal statements on variety-seeking

#	**Attitudinal statements**	**Factor**
A1	I am the kind of person who would try new products even if I'm satisfied with my current purchasing	need for variety
A2	If I did a lot of flying, I would like to try different airlines as much as I can, instead of flying just one most of the time	need for variety
A3	I like to try new routes to familiar destinations	need for variety
A4	A lot of the time I feel the urge to buy something really different from the products/ styles I usually get	need for variety
A5	I like to explore somewhere new, different or strange nearly every day	need for variety
A6	Whenever my life forms a stable routine, I look for ways to change it	need for variety
A7	If I like a brand, I rarely switch from it just to try something different	resistance to change
A8	I prefer a routine way of life to an unpredictable one full of change	resistance to change
A9	Even though certain food products are available in a number of different flavours, I tend to buy the same flavour	resistance to change
A10	Often, I feel a bit uncomfortable even about changes that may potentially improve my life	resistance to change
A11	I like to do the same old things rather than try new and different ones	resistance to change

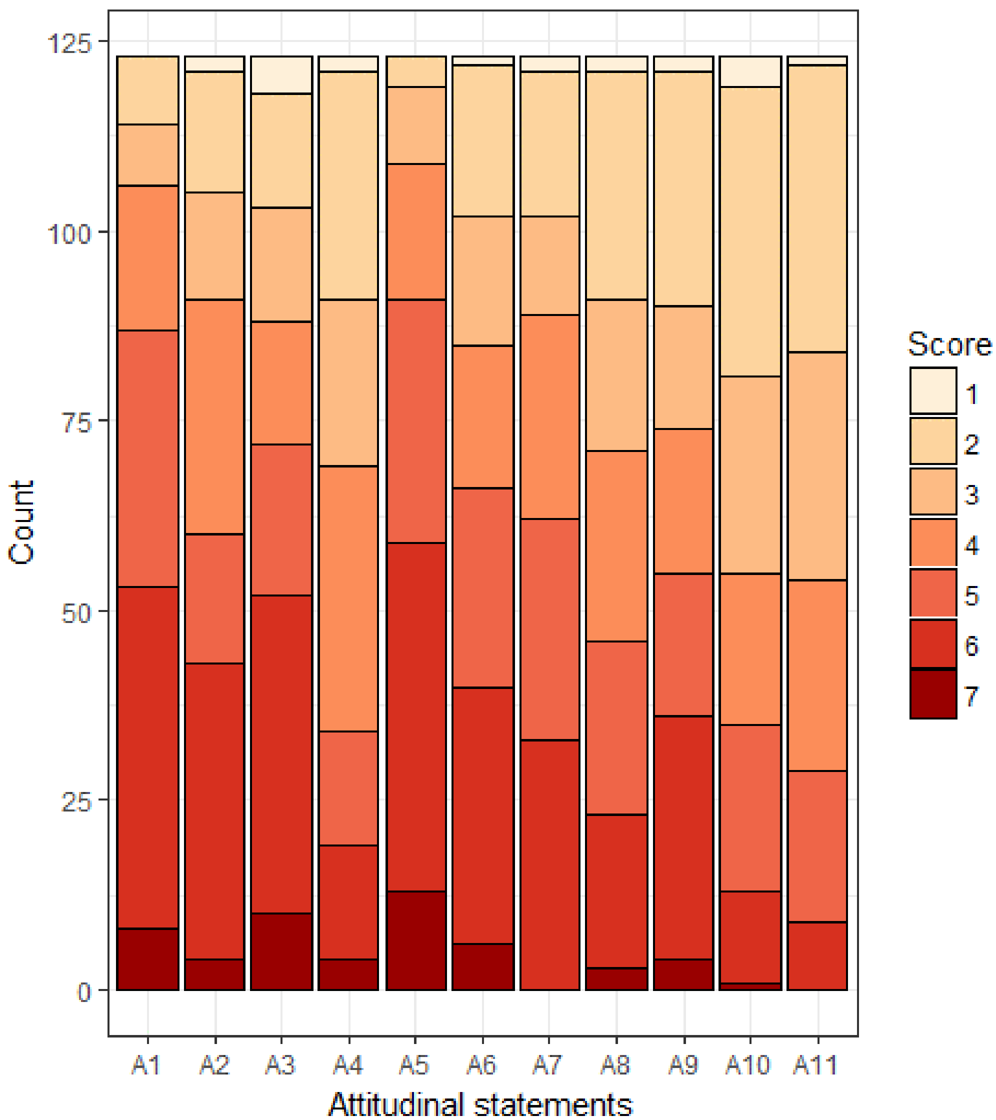

Figure 3: Responses to attitudinal statements

4.2. Mixed multinomial logit model (MMNL)

We next introduce random alternative-specific constant (ASC) to capture the unobserved variation of overall preferences towards each alternative across respondents, i.e. for a given alternative i, δ_{in} is random across respondents with a mean of μ_{δ_i} and a standard deviation of σ_{δ_i}, such that $\delta_{in} = \mu_{\delta_i} + \sigma_{\delta_i}\xi_{in}$, where ξ_{in} follows a standard normal distribution over respondents. Again, δ for one alternative is fixed to 0 for normalisation. Then the utility function can be given by:

$$U_{int} = V_{int} + \varepsilon_{int} = \mu_{\delta_i} + \sigma_{\delta_i}\xi_{in} + \beta' x_{int} + \omega_i' Z_n + \varepsilon_{int} \tag{3}$$

The unconditional choice probability for respondent n to make a sequence of choices is then specified as:

$$P_n = \int_{\delta_n} \prod_{t=1}^{T_n} P_{nt}\left(y_{nt}|\delta_n\right) f\left(\delta_n|\Omega_\delta\right) \mathrm{d}\delta_n, \tag{4}$$

where T_n is the number of choice tasks given to respondent n, δ_n is a vector of the random ASC for respondent n (i.e. $\delta_n = (\delta_{1n}, \ldots, \delta_{Jn})$), Ω_δ represents a collection of the corresponding distribution parameters for δ_n (i.e. $\Omega_\delta = (\Omega_{\delta_1}, \ldots, \Omega_{\delta_J})$, where $\Omega_{\delta_i} = (\mu_{\delta_i}, \sigma_{\delta_i})$), and f gives the density function. We define y_{nt} to be the alternative chosen by person n in choice situation t. As each respondent was required to complete 8 SC tasks in the survey, we estimate the MMNL model in a panel formulation by assuming that tastes vary across respondents but stays constant across choices for each respondent. The log-likelihood (LL) function can be written as:

$$LL(y) = \sum_{n=1}^{N} ln\left(\int_{\delta_n} \prod_{t=1}^{T_n} P_{nt}\left(y_{nt}|\delta_n\right) f\left(\delta_n|\Omega_\delta\right) \mathrm{d}\delta_n\right), \tag{5}$$

where N denotes the total number of respondents and y represents the choice outcomes observed by researchers. The resulting LL function does not have closed-form expression, and needs to be approximated through simulation. Suppose we take R draws from the distribution $f\left(\delta_n|\Omega_\delta\right)$ for each respondent and each random term, then the simulated log-likelihood can be expressed as:

$$SLL(y) = \sum_{n=1}^{N} ln\left(\frac{1}{R}\sum_{r=1}^{R}\prod_{t=1}^{T_n} P_{nt}\left(y_{nt}|\delta_n^r\right)\right) \tag{6}$$

4.3. Integrated choice and latent variable model (ICLV)

4.3.1. Model Framework

Directly incorporating responses to attitudinal statements as observable explanatory variables potentially leads to measurement error and endogeneity bias (Ashok et al., 2002; Kim et al., 2014). To deal with these issues, the ICLV model has become a commonly used approach to better account for the impact of the unobservable factors by treating them as latent variables. Figure 4 provides an illustration of our model structure which is based on the standard framework proposed in Ben-Akiva et al. (2002). The model consists of two components, which are a choice model and a latent variable model, each including structural equations and measurement equations. Items in rectangular can be directly observed by researchers and items in ellipse are unobserved. Solid arrows represent structural equations which describe the cause-and-effect relationships, while dashed arrows refer to measurement equations which explain indicators by latent variables or choices by utilities. Consequently, the latent variable model and the choice model are linked through the latent variable which is used to explain both attitudinal indicators in the measurement equations of the latent variable model and utilities in the structural equations of the choice model.

Under our ICLV structure, utilities are determined by both observable explanatory variables and the latent variable *variety-seeking tendency*, with the latter also being used to explain the corresponding attitudinal indicators. Therefore, the potential issue of endogeneity bias and measurement error could be corrected. Our ICLV model is estimated simultaneously through maximum likelihood estimation which leads to gains in efficiency compared to sequential estimation.

4.3.2. Choice model component

As shown in Eq.7, the structural equation in the choice model component gives the utility function which is determined by both observable explanatory variables and the latent variable on variety-seeking. In our notation, α_n denotes the latent variety-seeking tendency which varies over respondents, and τ_i measures variety-seeking's impact on the utility of alternative i, with one τ being fixed to 0 for identification.

$$U_{int} = V_{int} + \varepsilon_{int} = \mu_{\delta_i} + \sigma_{\delta_i}\xi_{in} + \tau_i\alpha_n + \beta' x_{int} + \omega_i' Z_n + \varepsilon_{int} \qquad (7)$$

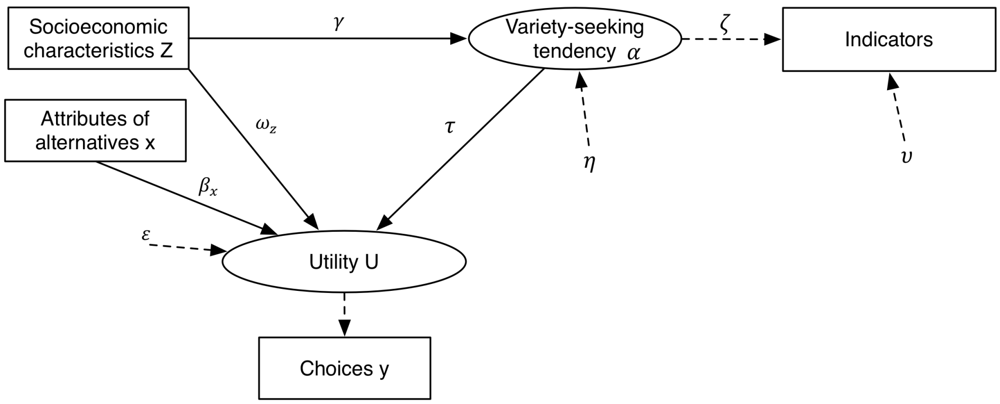

Figure 4: Framework of the ICLV model

4.3.3. Latent variable model component

The structural equation in the latent variable model component explains the latent variable by some observable socioeconomic characteristics Z_n, which is usually specified in a linear relationship with γ being the coefficient vector, such that:

$$\alpha_n = \gamma' Z_n + \eta_n, \tag{8}$$

where the stochastic error η_n follows a standard normal distribution across respondents, such that $\eta_n \sim N(0, 1)$.

In the measurement equations, responses to the attitudinal statements listed in Table 2 are treated as indicators to be explained by the latent variable of *variety-seeking tendency*, and each indicator requires a separate measurement equation. In recent years, a growing number of studies have recognized the ordinal characteristics of attitudinal indicators and have advocated the use of an ordered specification, as in Daly et al. (2012). For example, see Hess and Stathopoulos (2013) and Kamargianni et al. (2015). In this regard, the current paper differentiates itself from the work of Rieser-Schüssler and Axhausen (2012) by using an ordered specification instead of a continuous specification.

Following Daly et al. (2012), we use I_{nk} to denote the observed response to attitudinal statement k for respondent n. Using the coefficient ζ_k to measure the impact of the individual-specific latent *variety-seeking tendency* on the response towards indicator k, the probability of the observed response I_{nk}

can be written in an ordered logit form, such that:

$$P\left(I_{nk}=s|\alpha_n\right)=\frac{e^{\left(\mu_{k,s}-\zeta_k\alpha_n\right)}}{1+e^{\left(\mu_{k,s}-\zeta_k\alpha_n\right)}}-\frac{e^{\left(\mu_{k,s-1}-\zeta_k\alpha_n\right)}}{1+e^{\left(\mu_{k,s-1}-\zeta_k\alpha_n\right)}}, \tag{9}$$

where $\mu_{k,s}$ are threshold parameters, and $s \in (1,2,3,4,5,6,7)$ as a 7-point Likert scale was used.

For normalisation purpose, we set $\mu_{k,0}$ to $-\infty$ and $\mu_{k,7}$ to $+\infty$. Therefore, in our case, only the intermediate six threshold values can be estimated for each indicator.

4.3.4. Log-likelihood function

In the joint log-likelihood function, we need to maximise $LL(y,I)$, in which the unconditional probability P_n of observing choices y_n and attitudinal indicators I_n can be expressed as the integral of the multiplication of the conditional choice probability and the conditional indicator probability over all possible values of the latent variable, such that:

$$LL(y,I)=\sum_{n=1}^{N} lnP_n \tag{10}$$

$$P_n=\int_{\delta_n}\int_{\alpha_n}\left(\prod_{t=1}^{T_n}P\left(y_{nt}|x_{nt},Z_n,\alpha_n,\delta_n;\beta,\omega,\tau\right)\times\prod_{k=1}^{K_n}P\left(I_{nk}|\alpha_n;\mu_k,\zeta_k\right)\right) f\left(\alpha_n|Z_n;\gamma\right)f\left(\delta_n|\Omega_\delta\right)\mathrm{d}\left(\alpha_n\right)\mathrm{d}\left(\delta_n\right) \tag{11}$$

A second layer of integration is required to account for both unobserved heterogeneity and the latent variables. Again, the model is estimated using simulation to approximate the integrals.

5. Empirical analysis

5.1. Model specification

Three models were estimated, which examined the marginal utilities of varies explanatory variables and to different extent accounted for taste heterogeneity and the impact of variety-seeking on mode choice in the context of HSR-air intermodality. We started with a MNL model without considering the impact of variety-seeking, nor the random taste heterogeneity, based on the utility function specified in Eq.(1). We then estimated a MMNL model by including random alternative-specific constants to accommodate random taste heterogeneity, following the utility function given in Eq.(3). We finally estimated an ICLV model as addressed in section 4.3, in which variety-seeking tendency was treated as a latent variable in the utility function rather than an exogenous explanatory variable, and was also used in the measurement equations to explain the attitudinal indicators. The ICLV model accounted for the ordinal characteristics of attitudinal responses, and treated both age and income as continuous variables in the structural equation to explain the latent variety-seeking tendency. It should be noted that in order to ensure fair comparison between the first two models and the ICLV model and to avoid overstating the benefit of applying an ICLV model, both the MNL and the MMNL model incorporated age and income in the utility function in a linear way (Vij and Walker, 2016). Additionly, in both the MMNL model and ICLV model, the integrated HSR-air alternative was chosen as the base alternative for normalisation as it had the lowest variance in the unidentified model (Walker et al., 2007), and 500 Halton draws were used per individual per random component in simulation-based estimation.

In each model, minor time, travel cost and connection time were treated as continuous variables, while other attributes were dummy coded and entered the utility functions as categorical variables. Travel cost was a generic variable in each model. Minor time of car-air/air-air was differentiated from that of separated/integrated HSR-air, with each being further split between business travels and non-business travels. Delay protection was interacted with the response to ‘Are you familiar with the transfer city Shanghai’, a self-reported question with three available options (i.e. not familiar at all, familiar and very familiar). The attribute of luggage integration was interacted with the number of check-in luggage of the respondent for current travel.

5.2. Estimation results

5.2.1. MNL and MMNL models

The estimation results of MNL and MMNL models are presented in Table 4. The alternative-specific constant (ASC) for car-air is always negative, indicating that, all else being equal, the overall preference for car-air is lower than that of integrated HSR-air (i.e. the base alternative). No significant ASC for air-air or separated HSR-air is discovered, suggesting no underlying preference over or below integrated HSR-air.

The estimates for various utility parameters show similar patterns in MNL and MMNL models and almost all of them have expected signs - respondents derive a positive utility from reductions in travel time (including minor time, connection time, transfer time) and travel cost and from improvements in additional service, i.e. delay protection, and luggage integration. The only less intuitive finding arises for the insignificant estimates for ticket integration which is ambiguously perceived by respondents, a finding that could potentially be attributed to two reasons. Firstly, some respondents do not experience difficulties in purchasing/collecting tickets separately, thereby feeling no urge to pay for the integrated service; secondly, some respondents doubt whether integrated service could guarantee them the flexibility of choosing airlines on the major leg and do not want to rush into this new market when it is not fully developed.

Dividing the sensitivity of different minor time by the sensitivity of cost, we can obtain the value of time (VoT) for each group. The calculations of value of minor time are summarised in Table 3. It can be inferred that whether for business travellers or for non-business travellers, the VoT is much higher if the minor leg is made by car or air (i.e. car-air or air-air alternative) than by HSR (i.e. separated or integrated HSR-air alternative), reflecting the superior comfort experienced in high-speed trains. The VoT difference between car/air and HSR for business travellers might also be due to the fact that business travellers use more travel time for work than for other activities, and compared to working during car travel or air travel, working during train journeys is more favourable (Hultkrantz, 2013). The VoT of business travellers is about twice that of non-business travellers, suggesting that passengers would be more unwilling to spend longer time on the minor leg if they are travelling for business. Such findings of higher VoT for business travellers are consistent with other value-of-time studies. For example, González-Savignat (2004) discovered the value of travel time to be 55eur/h (37 eur/h) for business (leisure) travellers.

VoT studies in China are quite limited, and official VoT statistics are not available (Wu et al., 2014). Hultkrantz (2013) indicated the upper margin of VoT of business travellers by rail on the Beijing-Shanghai corridor to be 2.07 CNY/min through calculating the break-even VoT that equalises the generalised cost of HSR and air; Wang et al. (2014) obtained a VoT estimate ranging from 0.33 to 1.4 CNY/min for different types of HSR travellers on the intra-provincial Ningbo-Taizhou-Wenzhou corridor through nested logit model on revealed-preference data; Li and Sheng (2016) estimated the VoT for en route travel (relating to both minor leg and major leg) in the context of HSR-air intermodality based on stated-preference data, showing a highest VoT of 2.17 CNY/min for direct air travel, followed by 1.84 CNY/min for integrated travel, and 1.47 CNY/min for direct HSR travel. In contrast, our inferred VoT estimates are much higher but still comparable. This can be largely attributed to that our sample composition is not representative of the general Chinese population. Wu et al. (2014) suggested that the unbalanced economic development and the large income gap in China would result in huge variation of VoT across regions and income groups, and their estimates, which were derived based on the average wage and social welfare payment, showed that the VoT for business travellers of the highest 20% income group in Shanghai can reach 2.36 CNY/min, followed by provinces in the Yangtze River Delta regions. Since the majority of our respondents came from these developed regions and were on international travels in particular, it is reasonable to achieve higher VoT estimates. In addition, what we suggest here is the value of time for accessing the airport which is usually higher than that for the en route component given the high penalty associated with missing a flight.

Table 3: Value of time calculations

	Value of Time (CNY/min)			
	MNL	MMNL	ICLV	Change (%)
MinorTime_car/air_Business	6.45	7.58	6.83	-9.91
MinorTime_car/air_NonBusiness	3.50	4.38	4.62	5.55
MinorTime_HSR_Business	4.35	4.46	4.10	-8.14
MinorTime_HSR_NonBusiness	1.85	1.71	1.77	3.57

According to Table 4, connection time is perceived to be no less important than minor time except when the minor leg is made by car or air for business travellers, implying a great necessity of enhancing the coordination between air and HSR timetables. The significant negative estimate for transfer time suggests a strong dislike of moving between airports/ stations which are far away from each other. We did not find significant differences between the impact of 90min of transfer time and 45min of transfer time on mode choice, and this potentially means that passengers still feel averse to moving between two far-away airports/stations even if the transfer time could be reduced by half. Moreover, better delay protection is more attractive to passengers, and in particular, those who are unfamiliar with the transfer city Shanghai experience a higher positive utility from 'free flight change' (level 2) than those who know Shanghai well, which indicates that people lacking travel information may perceive more uncertainty in travel and are willing to pay more for reducing risks. Finally, people with more check-in luggage have a stronger preference for luggage integration than people with less check-in luggage, while passengers with at most one piece of check-in luggage do not significantly differentiate between luggage integration with two security checks (level 1) or one security check (level 2). This is not the case for passengers with more than one check-in luggage, where one security check is significantly more appealing than two security checks.

Age and income are incorporated in the utility function as continuous explanatory variables. As the impact of age on car-air and air-air, and income on air-air was not significant even at the 60% confidence interval, we excluded them from the final models. The results show that respondents' preference towards separated HSR-air decreases with age, which potentially results from the stronger inconvenience of separated service perceived by older passengers. The less significant estimates for income suggest that passengers with higher income might potentially derive more utility from the car-air or separated HSR-air alternatives compared to air-air or integrated HSR-air alternatives.

Moving from MNL models to MMNL models, a very significant improvement in model fit is observed. The standard deviation of ASC for each alternative is significantly different from 0, where car-air presents the highest randomness compared to integrated HSR-air, followed by separated HSR-air and air-air. This confirms the existence of random heterogeneity across respondents in modal preferences.

5.2.2. ICLV model

In reporting the estimation results of the ICLV model, the overall log-likelihood and the log-likelihood for the choice model component are presented in the last two columns of Table 4. Compared to the MMNL model without the incorporation of variety-seeking, we cannot discover significant improvement in the choice log-likelihood of the ICLV model. This is consistent with the discussions in Vij and Walker (2016); since an ICLV model needs to explain both choice indicators and measurement indicators, the overall log-likelihood can never be better than that of the corresponding reduced form mixed logit model (i.e. MMNL). It can, however, of course give us different insights into behaviour.

We turn to the results for the measurement equations in the latent vari-

Table 4: Model estimation results

	MNL		MMNL		ICLV	
LL	-1136.04		-1035.19		Choice: -1034.743 Total LL: -2773.397	
	Est.	t-rat.	Est.	t-rat.	Est.	t-rat.
$\mu_{\delta_{car-air}}$	-2.140	-3.01	-2.959	-2.82	-3.335	-3.01
$\mu_{\delta_{air-air}}$	-0.012	-0.04	0.174	0.44	0.176	0.45
$\mu_{\delta_{separatedHSR-air}}$	-0.169	-0.53	-0.520	-1.24	-0.554	-1.30
$\sigma_{\delta_{car-air}}$	-	-	-2.264	-7.48	-2.254	-4.84
$\sigma_{\delta_{air-air}}$	-	-	-0.965	-6.23	-0.959	-6.35
$\sigma_{\delta_{separatedHSR-air}}$	-	-	1.438	8.12	1.347	9.08
$AGE_{separatedHSR-air}$	-0.427	-2.67	-0.454	-2.34	-0.566	-2.85
$INCOME_{car-air}$	0.241	1.77	0.282	1.41	0.311	1.60
$INCOME_{separatedHSR-air}$	0.126	1.39	0.124	1.03	0.186	1.46
$\beta_{MinorTime\_car/air\_Business}$	-0.013	-3.30	-0.018	-3.28	-0.017	-2.85
$\beta_{MinorTime\_car/air\_NonBusiness}$	-0.007	-2.56	-0.011	-2.97	-0.011	-3.06
$\beta_{MinorTime\_HSR\_Business}$	-0.009	-4.10	-0.011	-3.93	-0.010	-3.61
$\beta_{MinorTime\_HSR\_NonBusiness}$	-0.004	-2.39	-0.004	-2.18	-0.004	-2.30
$\beta_{ConnectionTime}$	-0.009	-8.66	-0.011	-8.70	-0.011	-8.65
$\beta_{TransferTime=45/90min}$	-0.633	-5.47	-0.801	-5.71	-0.801	-5.75
$\beta_{DelayProtection=lv1}$	0.281	2.24	0.338	2.30	0.340	2.31
$\beta_{DelayProtection=lv2\&unfamiliar}$	0.693	3.51	0.670	2.98	0.653	2.90
$\beta_{DelayProtection=lv2\&familiar}$	0.369	2.54	0.479	2.98	0.491	3.10
$\beta_{TicketIntegration=lv2}$	0.155	0.94	0.203	1.08	0.193	1.03
$\beta_{TicketIntegration=lv3}$	-0.135	-0.82	-0.026	-0.14	-0.039	-0.22
$\beta_{LuggageIntegration=lv12\&\leq 1luggage}$	0.362	2.04	0.388	1.98	0.413	2.13
$\beta_{LuggageIntegration=lv1\&>1luggage}$	0.564	1.97	0.714	2.24	0.690	2.12
$\beta_{LuggageIntegration=lv2\&>1luggage}$	0.923	3.74	0.920	3.14	0.894	3.02
$\beta_{TravelCost}$ (CNY)	-0.002	-6.11	-0.002	-6.07	-0.002	-6.13
$\tau_{car-air}$	-	-	-	-	-0.907	-4.28
$\tau_{air-air}$	-	-	-	-	-0.008	-0.06
$\tau_{separatedHSR-air}$	-	-	-	-	-0.310	-1.94

able component in Table 5 before looking at the estimates for the choice model component in Table 4. All the attitudinal indicators, except for A4 and A9, are found to be affected by the latent variables as the corresponding ζ are significant for those indicators. Thus indicator A4 and A9 dropped out in the final models. The positive signs of $\zeta_k(k = 1, 2, 3, 5, 6)$ and negative signs of $\zeta_k(k = 7, 8, 10, 11)$ show that stronger latent variable α would lead to an increase in the response to the attitudinal statements A1, A2, A3, A5 and A6, which means an increase in the extent that the respondent agrees with the statement, and meanwhile would result in a lower score on the attitudinal statements A7, A8, A10 and A11, which means a stronger disagreement with the statement. This means that α stands for the 'variety-seeking tendency'. In addition, the uneven gap between thresholds proves the necessity and superiority of adopting an ordered logit formation to account for the ordinal characteristics of attitudinal indicators in measurement equations. It should be noted that since no respondent provided a score of 1 for A1 and A5, and no respondent provided a score of 7 for A7 and A11, threshold coefficients μ_1 for A1 and A5 as well as μ_6 for A7 and A11 are not estimated. The relationships between latent variety-seeking tendency and socioeconomic characteristics is detected to some extent in the structural equations: γ_{Age} is estimated to be -0.300 (t-stat: -2.76) and γ_{Income} to be 0.143 (t-stat: 1.78). This implies that younger people or people with higher income tend to have stronger variety-seeking tendencies.

Back to Table 4, the signs for all the ASC and utility coefficients are identical to those obtained in the MNL and MMNL models, and are not discussed here for brevity. As for the estimates for the marginal impact of the latent variables on utility, our results show that an increase of the latent variety-seeking tendency leads to a lower utility for car-air or separated HSR-air (given the negative sign for $\tau_{car-air}$ and $\tau_{separatedHSR-air}$), and that variety-seeking does not result in a difference in modal preference between air-air and integrated HSR-air. This implies that people who have weaker variety-seeking tendencies are more likely to choose car-air or separated HSR-air, and variety-seekers have a higher propensity to choose the air-air alternative or the new integrated HSR-air alternative.

It is also of interest to see what share of the random heterogeneity in the choice model can be attributed to the latent variables (see Table 6). This can be obtained by calculating the ratio of the variance of randomness induced by the latent variable and the variance of total randomness. For the heterogeneity in the car-air alternative, we see that 86.06% is pure random heterogeneity, while the remaining 13.94% is linked to the latent variety-seeking variable. For air-air, the share of the random variance is much higher, at 99.99%, leaving little explanatory power for the latent construct. For separated air-HSR, we see that 5.04% can be attributed to the latent variety-seeking tendency. Overall, these findings support the notion that variety-seeking plays a role in mode choice behaviour in our sample, albeit a small one.

Finally, if we look at the last column in Table 3 which summarises the changes of different value of minor time between the MMNL model and the ICLV model. It can be implied that the VoT for business travellers might be overestimated while the VoT for non-business travellers might be underestimated if the impact of latent variety-seeking tendency is not accounted for in a MMNL model.

6. Discussions and conclusions

This paper focuses on mode choice behaviour in the recently-emerged intercity travel market of HSR-air intermodality in China. It looks in particular at how variety-seeking could influence the mode choice decisions in this new context. Our research is motivated by two distinct factors. Firstly, although a large body of research on variety-seeking has been accumulated in consumer marketing, limited knowledge of its effect is available in the transport realm, whilst various novel transport services have emerged in recent years, such as low-emission vehicles and shared vehicles. HSR-air intermodality is a key example of such a new service for the majority of Chinese people. Secondly, though many researchers have initiated discussion on the cooperation between air and HSR in the perspective of pricing strategy, traffic volume and welfare analysis, etc., limited econometric studies has been conducted to investigate the mode choice behaviour on an individual level in this context. Following previous Spanish research, we carry out a comparable study in China, which has the world's largest HSR network and enjoys a rapid and steady increase in international travel, implying a great potential for enhancing cooperative intermodality between the two systems of air and HSR.

An integrated choice and latent variable (ICLV) model is estimated in this paper to account for the impact of latent variety-seeking tendency in mode choice behaviour in the new context of HSR-air intermodality. Variety-seeking is used to explain both the attitudinal indicators in measurement equations and the choices made in the stated preference survey. The results

Table 5: Estimation results of the measurement equations of the ICLV model

Indicator	ζ		μ_1		μ_2		μ_3		μ_4		μ_5		μ_6	
	Est.	t-rat.	Est.	t-rat.	Est.	t-rat.	Est.	t-rat.	Est.	t-rat.	Est.	t-rat.	Est.	t-rat.
A1	0.652	2.74	-	-	-2.922	-7.24	-2.164	-6.62	-1.131	-4.39	0.131	0.53	2.672	6.53
A2	0.539	2.30	-4.411	-5.90	-2.018	-6.26	-1.259	-4.76	-0.095	-0.40	0.515	2.17	3.412	6.11
A3	0.688	2.56	-3.633	-6.10	-2.001	-5.28	-1.205	-3.68	-0.566	-1.92	0.151	0.55	2.415	6.27
A5	0.870	3.37	-	-	-4.018	-6.85	-2.551	-7.00	-1.416	-4.65	-0.150	-0.55	2.183	5.95
A6	1.354	4.16	-6.301	-4.32	-2.548	-4.62	-1.529	-3.30	-0.649	-1.56	0.554	1.44	3.488	5.50
A7	-0.805	-2.99	-4.231	-6.19	-1.508	-4.91	-0.809	-2.89	0.254	0.87	1.387	4.07	-	-
A8	-1.726	-4.43	-5.264	-6.15	-1.067	-2.23	0.041	0.09	1.341	2.75	2.743	4.64	5.651	5.43
A10	-1.230	-3.65	-3.841	-6.26	-0.478	-1.32	0.654	1.83	1.574	4.05	3.059	6.21	6.005	5.56
A11	-1.794	-3.58	-6.151	-5.47	-0.603	-1.29	0.931	2.00	2.310	4.13	4.248	5.63	-	-

Table 6: Sources of random taste heterogeneity

	Components of variance of δ					Random taste heterogeneity %	
	σ	τ	pure random	linked to the latent variable	combined	pure random	linked to the latent variable
car-air	-2.25	-0.91	5.08	0.82	5.90	86.06%	13.94%
air-air	-0.96	-0.01	0.92	0.00	0.92	99.99%	0.01%
separated HSR-air	1.35	-0.31	1.81	0.10	1.91	94.96%	5.04%

of ICLV model show that variety seekers have a stronger propensity of choosing the new integrated HSR-air compared to car-air and separated HSR-air, while variety-seeking tendency does not have a significantly different impact between choosing air-air and integrated HSR-air. The most negative impact of variety-seeking on car travel compared to other public modes on minor leg confirms the findings in Rieser-Schüssler and Axhausen (2012), which also reflects the strong barrier of shifting drivers from behind their steering wheels to use public transport. In the structural equations, we used respondents' age and income to explain the latent variable which is interpreted as variety-seeking tendency. Results suggest that younger people and people with higher income present stronger inclinations to seek variety. Therefore the HSR sector, airports and airline companies need to make a joint effort in identifying variety seekers and trying to keep those new customers by providing them with enjoyable travel experience.

Turning to the impact of the level-of-service attributes, we observe higher values of minor time for business travellers compared to non-business travellers, and higher values of time if the minor leg is made by car or air than by HSR. This suggests that business passengers require shorter feeder journeys, and HSR travel is potentially perceived by either business travellers or non-business travellers as more comfortable than car travel or air travel. It is also shown that minor time is not more important than connection time except for the case for business travellers for the car-air or air-air alternative. This suggests the great necessity to improve the timetable coordination between flights and HSR trains as passengers dislike waiting at the departure airport for the major leg, which confirms the findings in previous studies (Li and Sheng, 2016; Román and Martín, 2014). Transferring between the Hongqiao Hub and Pudong International Airport is perceived as very inconvenient by intercity travellers, which indicates a sound prospect of attracting integrated HSR-air customers should the Pudong Hub be established. The higher the level of delay protection is, the more appealing it is to intercity passengers, with free flight change being the most attractive level; moreover, the free flight change in case of HSR delays resulting in failure to board the plane on the major leg is in particular more attractive to passengers who are not familiar with the transfer city Shanghai. Therefore it is necessary for policy makers and transport operators to clarify the rights and responsibilities of different sectors, and to establish practical mechanisms to protect passengers' travel as well as to attract more potential customers. Better integrated luggage handling service is welcomed by passengers, especially those with more luggage. Therefore, it would attract more customers if the integrated luggage handling system is available. However, we also need to be aware that such types of configuration updates might be very costly, therefore cost-benefit analysis is further required before policy makers decide to implement luggage integration system. Finally, the impact of ticket integration is much less clear, potentially suggesting that this is a less important attribute to look at for passengers. However from the perspective of system management, the advancement in other service attributes, e.g. better timetable coordination between flights and HSR trains, stronger delay protection and higher level of luggage integration, cannot be achieved without the implementation of a well-rounded integrated ticketing system which ensures a high level of information-sharing among stake-holders of the HSR system and air system. In this regard, ticket integration should still be considered as an important factor for improving the integrated HSR-air service. Moreover, integrated ticketing systems could reach wider customers only when it is capable of providing passengers with sufficient options on departure time and airline companies, otherwise passengers might feel a barrier to try the integrated HSR-air service.

Apart from the improvement of all the level-of-service attributes mentioned above, we also consider it essential to launch active advertisement for the integrated HSR-air product. Since the majority of our respondents have little knowledge about HSR-air intermodality, passenger demand would potentially increase if the general public are better aware of the integrated service. This could in particular contribute to attract more variety-seekers who would have a higher tendency to try the new integrated HSR-air service, among which those younger people and higher-income people should be treated as the targeted customers.

For comparison, a basic MNL model and a MMNL model are estimated along with the ICLV model. Random taste heterogeneity is accounted for through random ASC specification in both MMNL and ICLV models; and the significant estimates of the standard deviation of random ASC confirm the existence of random taste heterogeneity across respondents and across alternatives.

In closing, we put forward some avenues for future research. Firstly, it is worth investigating the impact of respondents' actual travel experience on their behaviour in the stated choice scenarios. Secondly, although our results have identified that younger people seek more variety and are more inclined to try the integrated HSR-air service, we cannot be sure that they would not gradually become more resistant to change when they grow older, or whether the variety-seeking pattern of those young people would be kept unchanged. This issue would not be limited to our context of HSR-air intermodality, and in order to address it, it would be interesting to collect longitudinal data which enables researchers to understand how variety-seeking tendencies evolve over time and and influence choice behaviour. Thirdly, as mentioned in the text, our study only focuses on the short-run impact of variety-seeking in a stated preference survey, which could be equivalently interpreted as novelty-seeking. It is therefore worthwhile to further investigate the impact of variety-seeking tendencies in altering among different choices. Finally, it would improve the study if both the two different choice scenarios - minor leg comes before/after major leg - were presented to respondents, as this would enable the researchers to detect the difference between respondents' sensitivities of the various alternative-specific attributes in each direction of travel.

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