EXPLORING THE INTERMODAL PASSENGER TRANSFER OF A HIGH SPEED RAIL SYSTEM

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ABSTRACT

Intermodal seamless transportation plays an essential role to the success of a High Speed Rail (HSR) system's operation. This study aims to investigate the intermodal passenger transfer of Taiwan's high-speed rail system from the policy planner's and the passengers' perspectives. First, this study applies the Fuzzy Analytic Hierarchy Process (FAHP) based on relevant experts' opinions to analyze HSR passengers' intermodal transfer behavior from a policy planner's perspective in order to find an improvement strategy. Second, correspondence analysis is adopted to observe possible transfer patterns and concerned service attribute variables when selecting the HSR feeder transportation system from the passengers' perspective. This study adopts three main categories of HSR stations to analyze a passenger's intermodal transfer behavior.

The findings of this study are summarized as follows. The FAHP analysis indicates passenger convenience and urban planning integration are the two most important factors for HSR passenger transfers to the final destination. In regards to the passengers' perspectives, most passengers tend to use private vehicles instead of public transportation, indicating that the public transportation service for HSR transfer needs to be further improved. Several policy suggestions are included, which could be useful for the decision makers of transportation systems' planning, the central government, and the local authority so as to derive a comprehensive HSR intermodal planning strategy for a more integrated transportation system.

Keywords: High Speed Rail system, Transfer, Correspondence Analysis, Analytic Hierarchy Process

1. INTRODUCTION

The High Speed Rail (HSR) system has been considered as a safe, comfortable, and efficient mode of transportation (Arduin and Ni, 2005; Cheng, 2010). Since the HSR system mainly provides intercity transportation service, HSR stations can be regarded as hubs and thus provide proper feeder mode service that is necessary for passengers. Furthermore, transfer service has been proven as a critical element for public transportation system scheduling and network design and it can further influence passengers' perceptions of transit service quality (Guihaire and Hao, 2008).

Taiwan High Speed Rail (THSR) started revenue operations in 2007 with 8 stations in operation, but most of them are located in rural areas, thus increasing the inconvenience for passengers' accessibility to the stations. Previous studies have proven that the quality of transfer systems has a great impact on rail use and passengers' satisfaction (Givoni and Rietveld, 2007; Brons et al., 2009). Researchers show evidence that a railway station's location does influence whether people make use of rail services. People who live at a distance between 500 to 1000 meters from a train station use rail services 20% less than those who live at most 500 meters from the station (Keijer and Rietveld, 1998). As a result, how to improve transfer systems and the accessibility of THSR stations are critical problems for the HSR system operator.

Taiwan's government and the Taiwan High Speed Rail Corporation (THSRC) originally expected that THSR stations could be a catalyst to stimulate a change in regional social–economic characteristics of the stations' surrounding areas, believing that they would raise property values for the entire surrounding areas and attract development and population to those regions. The planning philosophy changed to set up HSR's links into local systems at points outside of city centers (Cheng, 2010). THSR stations were placed at the periphery of the city centers for the regions they currently serve. However, such poor accessibility between HSR stations and city centers needs to be further examined.

An HSR's feeder system service provided at various types of HSR stations and feeder mode service attributes are also important determinants considered by passengers. Without knowing passengers' preference on transfer mode choice behavior, it would be difficult for the authority and THSR service providers to design appropriate HSR transfer services. It is essential to create a comprehensive HSR feeder system service while at the same time considering various passengers' personal background and their trip characteristics. Rastogi and Rao (2003) also indicated that household/individual demographic characteristics and system attributes, such as frequency and availability of access modes, influence passengers' mode choices.

THSR has already cooperated with other transportation service providers, such as buses, a conventional railway system (Taiwan Railways Administration, TRA), and a mass rapid transit (MRT) system, but not all of the THSR stations provide exactly the same transfer service. We thus aim to identify which types of transfer choices are appropriate for passengers at various HSR stations. This present study takes HSR stations as departure origins and evaluates passengers' transfer system preference to the final destinations. Each of these stations provides different transfer services and this will be clearly illustrated in a later paragraph. Because most of the THSR stations are far from center business districts (CBD), walking is not considered as one of the feeder modes in this study. Moreover, passengers' preference and demographic characteristics might influence their mode choices.

The transfer demand analysis from the HSR's passenger's perspective is an essential input for the transport planner to design and successfully provide HSR's feeder system service. The evaluation framework on choosing a suitable alternative derives from relevant experts' opinions, HSR passengers' transfer demand analysis, and previous literature. Based on the expert opinions and choice, this study finds the key determinants to develop a sustainable and integrated feeder network. This study thus aims to investigate the intermodal passenger transfer of the THSR system from a policy planner's and passengers' perspectives and compares their difference and their gap.

This study is divided into 4 main sections. Section 1 briefly introduces the research background in this study. Section 2 describes the research design and methodology adopted in this study. Empirical results are presented in Section 3. Finally, section 4 includes conclusions and discussions.

2. RESEARCH DESIGN AND METHODOLOGY

This study first aims to investigate HSR passengers' transfer choices based on the HSR passenger transfer demand analysis and then creates an evaluation framework from the transport planner's perspective in order to identify the factors which influence passengers' behavior by the weighted values obtained by fuzzy multiple criteria decision making (fuzzy MCDM). From the viewpoint of a policy planner, we evaluate the alternatives' weighted values by Fuzzy analytic hierarchy process (FAHP). This study can design the transfer system provided at each THSR station by using the results based on the HSR passengers' transfer demand analysis and FAHP analysis from the policy planner's perspective.

2.1. THSR passenger transfer demand analysis

HSR passengers' transfer mode choices involve factors concerning multiple criteria, personal background, and trip characteristics. Therefore, this study first observes whether there is a difference between passengers' demographic and trip characteristics on their transfer mode choices. This study investigates HSR passengers' transfer behaviour choices following the flow chart (Figure 1).

HSR passengers' feeder mode choice differs from station to station. To examine whether passengers behave differently in their transfer choices at various THSR stations, this study classifies the 8 stations into 3 categories according to the feeder mode service provided. Stations in the Type I group provide only parking spaces for private vehicles and motorcycles, while also having park and ride areas, taxi stations, and bus stations. Except for the feeder modes included above, Type II stations additionally provide conventional railway feeder service, and Type III stations additionally provide conventional railway feeder service and MRT service. Table 1 presents the classification.

Table 1 – Classification of THSR stations

	Type I	Type II	Type III
Feeder modes	• Taxis • Bus • Private car	• Taxis • Bus • Conventional railway	• Taxis • Bus • Conventional railway • MRT
Stations	Taoyuan Hsinchu Chiayi Tainan	Taichung Zuoying (Kaohsiung)	Taipei Banciao

2.2. Panorama analysis from a policy planner's perspective

This study aims to combine the criteria emphasized by passengers to conduct the panorama analysis so as to realize a more comprehensive THSR transfer system planning. The processes of conducting FAHP are described as follows.

Step 1: Establish an evaluation framework from a policy planner's perspective
This study includes 3 main dimensions: passenger safety and convenience, urban planning integration, and economic issues. Factors under the 3 main dimensions are then adopted by reviewing the relevant literature and the results obtained in passenger transfer demand analysis. Figure 2 presents the AHP evaluation framework.

In order to establish the AHP evaluation framework, the main research problems need to be clearly defined at first. Through experts' evaluation, we realize the level of importance in THSR's transfer system planning and the feeder alternatives evaluated by the experts. Second, evaluation dimensions should be determined. This study obtains criteria included in the dimension of "passenger safety and convenience" by our HSR passenger transfer demand analysis. Factors included in the dimensions such as urban planning integration and economic issues are obtained from previous literature (Halden, 2002; Meyer and Miller, 2001; Waddell et al., 2007) and definitions are presented in Table 2. Alternatives are generated based on real recommendations at THSR stations.

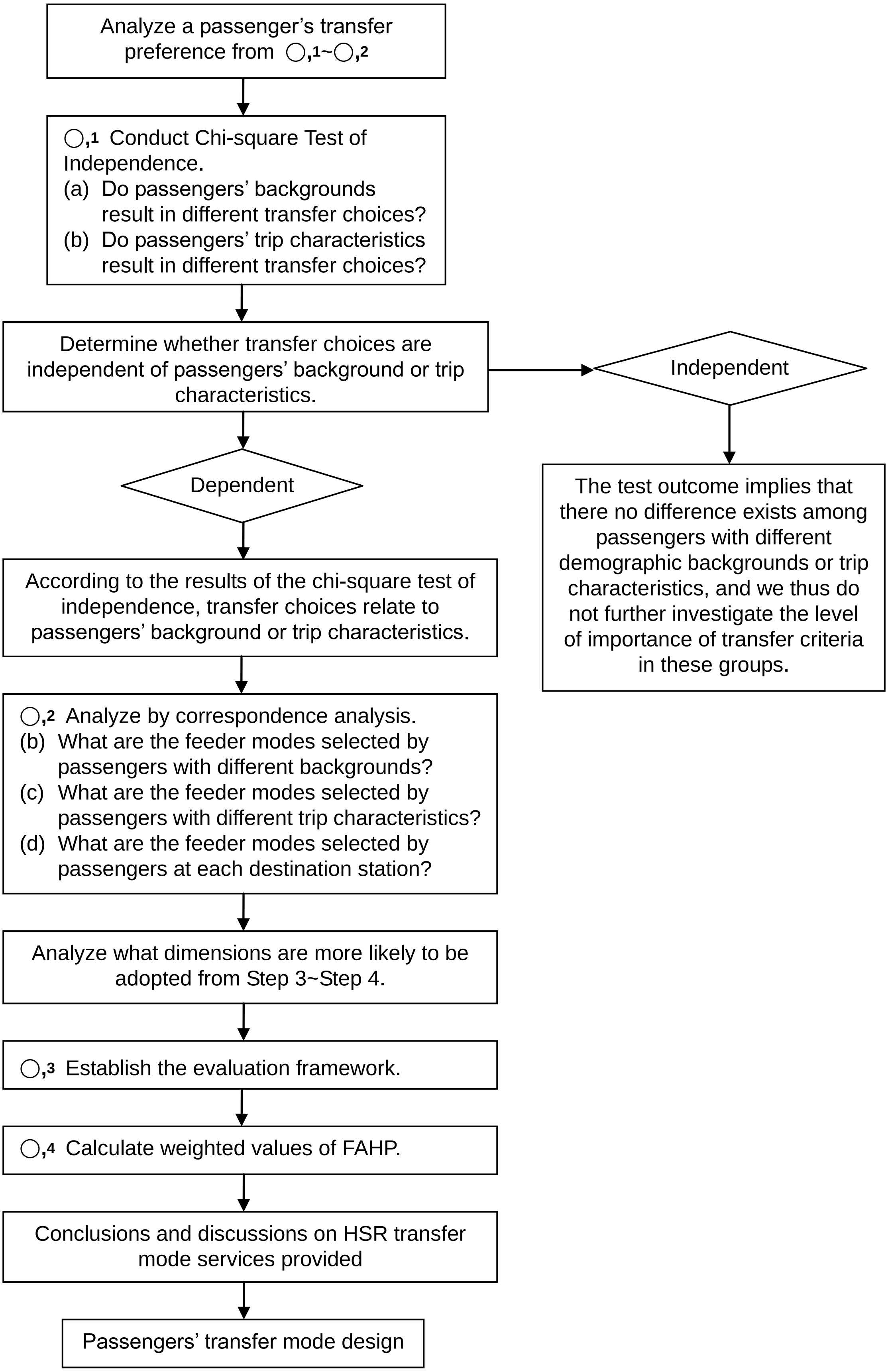

Figure 1 – The flow chart for analyzing passengers' transfer behavior

Step 2: Construct fuzzy pair-wise matrix of key factors

Through a questionnaire survey, experts' option importance comparison can be obtained and then fuzzy estimation values can be calculated. The fuzzy paired comparison matrix is as follows.

$$\tilde{A}^k = \left[a_{ij}^k\right] \tag{1}$$

where:

$\tilde{A}^k$: the k^th expert's fuzzy positive reciprocal matrix.

a_{ij}^k : the k^th expert on i^th option's importance comparison value.

Step 3: Consistency analysis

A rational policy maker's or an expert's preference structure should fit the assumption of transitivity, and the outcomes of pair comparison should thus fit the same assumption as well. This study applies a consistency index (CI) to test the consistency. According to Saaty (1980), CI=0 indicates that the decision is consistent. When CI $>$ 0, it indicates inconsistency of a policy maker's decision. Moreover, if CI $\leq$ 0.1, then it implies inconsistency, but we still can accept it as a biased error. In this study, consistency indices were examined by Expert Choice 2000 software.

All the CI of dimensions, factors, and alternatives were less than 0.1, indicating an acceptable consistency in policy makers' decisions.

Step 4: Calculate the fuzzy weighted value of each dimension

$$Z_i = \left[\tilde{a}_{i1} \otimes \ldots \otimes \tilde{a}_{in}\right]^{1/n}, \ \forall i \tag{2}$$

$$\tilde{w}_i = Z_i \otimes \left[Z_1 \oplus \ldots \oplus Z_n\right]^{-1} \tag{3}$$

Where:

$\tilde{a}_{ij}$: the triangular fuzzy value in the i^th row and the j^th column.

Z_i : the geometric mean of triangular fuzzy value.

Step 5: Defuzzification

This study applies the center-of-gravity method to transfer fuzzy values into a best non-fuzzy performance (BNP) value, and the BNP value of the fuzzy value, $\tilde{w}_j$, can be calculated by the following function.

$$BNP = \left[\left(Uw_j - Lw_j \right) + \left(Mw_j - Lw_j \right) \right] / 3 + Lw_j \ , \ \forall j \tag{4}$$

Table 2 – Definitions of assessing criteria

Dimensions	Factors	Definitions
Passenger Safety and Convenience	Convenience	Improving accessibility of THSR stations and making passengers' journey much smoother and easier.
	Quickness	Reduction of travel time, such as in-vehicle time and waiting time, is one of the critical elements for transportation planning.
	Safety	Avoiding accidents by improving service quality and decreasing congestion.
Urban planning integration	HSR stations' surrounding area renovation	Promoting urban development and improving urban environment by developing transportation hubs and industry transformation.
	Integrating regional transportation network	Improving integration of urban network and roads around THSR stations.
Economic issues	Job opportunity creating	Developing well-designed transfer systems and thus creating job opportunities in these systems.
	External cost consideration	The external costs include air pollution, noise pollution, energy consumption, etc., brought about by transportation systems.
	Increasing revenue from developing station areas	THSR stations change the land use in surrounding areas and thus promote industrial development.

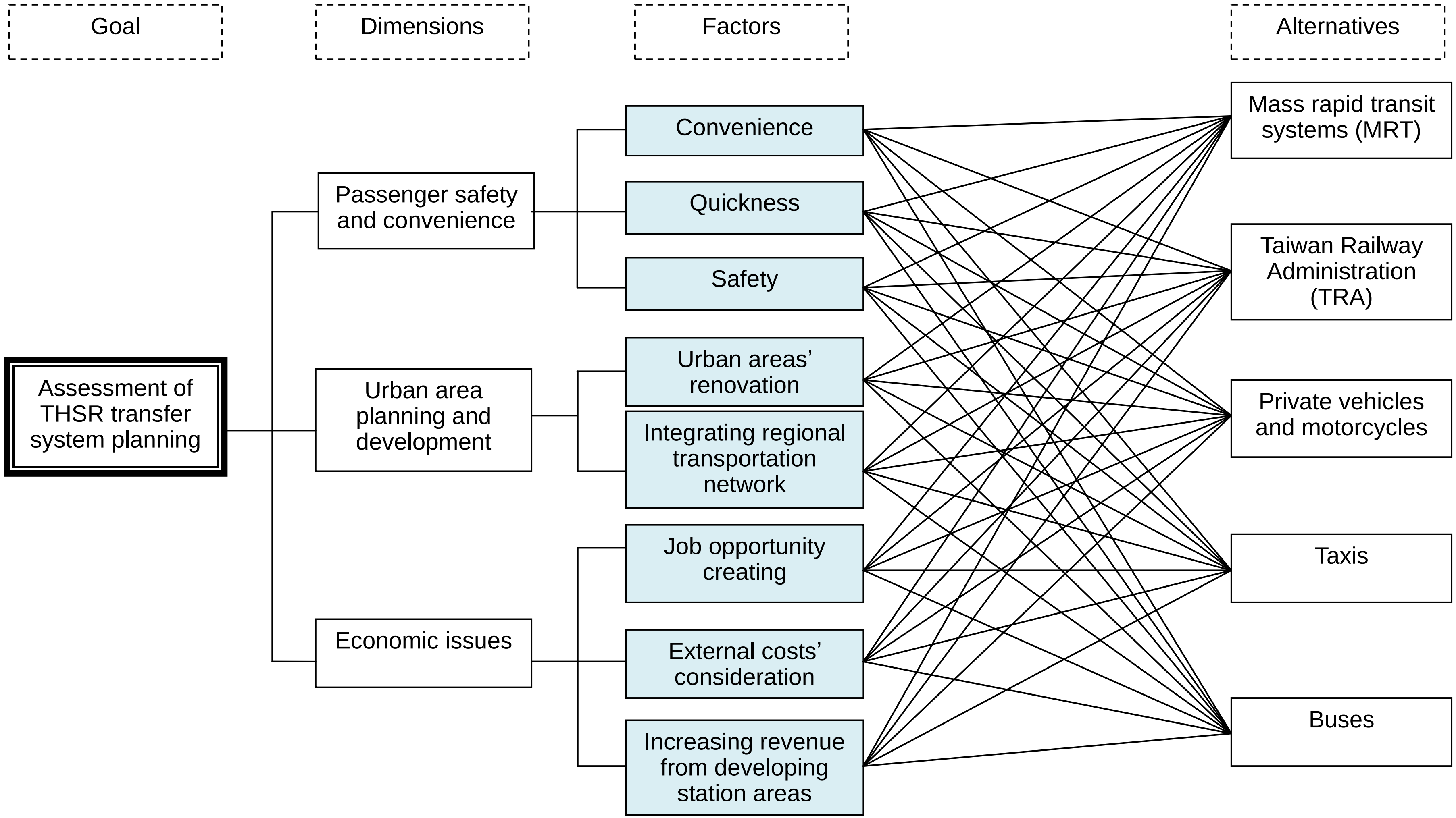

Figure 2 – The AHP 's evaluation framework of THSR transfer system planning

3. RESULTS

3.1. THSR passenger transfer demand data collection

The questionnaire survey was conducted at 8 THSR stations: Taipei, Banciao, Taoyuan, Hsinchu, Taichung, Chiayi, Tainan, and Zuoying (Kaohsiung) stations. We consider the transfer behaviour choice when they leave the HSR stations to the final destinations. The research range in this study is circled by a red dotted line as follows (Figure 3). We invited passengers who have had transfer experiences at THSR stations or those who travel by THSR for the first time to fill out the questionnaires.

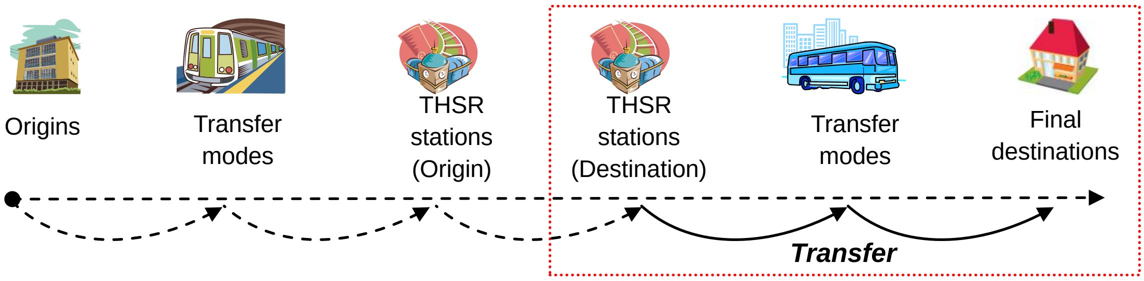

Figure 3 – The research scope of this study

This study's questionnaire contains three main components, including personal information, trip characteristics, and level of importance of factors for transfer choices. For personal information, we include questions related to passengers' demographic background, trip characteristics, origin and destination stations, and transfer choices. In order to realize which factors actually influence passengers' transfer choices, questions in this component include attributes of different feeder modes. To measure the levels of importance of each item, this study uses a five-point Likert scale rating from 1, representing not important at all, to 5, extremely important. In addition, for considering different transfer behavior of business and non-business travellers, this survey was carried out the survey on both weekdays and holidays.

Table 3 – Distribution of surveys collected at various stations (N=322)

Station	Frequency	Percentage (%)	Accumulated percentage (%)
Taipei	80	24.84	24.84
Banciao	23	7.14	31.98
Taoyuan	19	5.90	37.88
Hsinchu	17	5.28	43.16
Taichung	45	13.98	57.14
Chiayi	17	5.28	62.42

Tainan	31	9.63	72.05
Zuoying	90	27.95	100.00

A total of 348 questionnaires were distributed and 322 valid samples were obtained (92.53% response rate). Our survey was conducted at THSR stations, the distribution of surveys collected at each station is presented in Table 3. Over half of the samples were acquired at Zuoying, Taipei, and Taichung stations and a possible explanation is that these stations represent the three major metropolises along the western corridor in Taiwan. Therefore, they naturally become important trip attractions. Specific trip characteristics and demographic information are presented in Table 4 and Table 5, respectively. The survey's reliability was confirmed by Cronbach's α coefficient. According to Guieford (1965), Cronbach's α＞0.7 implies a high reliability. Cronbach's α between 0.35 and 0.7 is acceptable. Cronbach's α of the overall questionnaire survey equals 0.858, and Cronbach's α of each factor lies between 0.613 and 0.960, which indicates our results have high reliability.

Table 4 – Trip characteristics of respondents (N=322)

Trip characteristics	Frequency	Percentage (%)	Accumulated percentage (%)
Commuter trip	14	4.35	4.35
School trip	6	1.86	6.21
Inbound journey of a business trip	50	15.53	21.74
Outbound journey of a business trip	93	28.88	50.62
Inbound journey of a leisure trip	50	15.53	66.15
Outbound journey of a leisure trip	34	10.56	76.71
Personal visit to hometown	57	17.70	94.41
Others	18	5.59	100

Table 5 – Demographic information of respondents (N=322)

Demographic variables		Frequency	Percentage (%)
Gender	Male	195	60.60
	Female	127	39.40
Age	≦20	13	4.04
	21－30	131	40.68
	31－40	107	33.23
	41－50	52	16.15

	≧51	17	5.90
Education	Elementary school or less	1	0.31
	Junior high school	2	0.62
	High school	48	14.91
	University	201	62.42
	Post-graduate degree	70	21.74
Monthly income	≦20,000 NTD	58	18.01
	20,001－40,000 NTD	106	32.92
	40,001－80,000 NTD	111	34.47
	≧80,001 NTD (1 U.S dollar =33 NTD)	47	14.60
Occupation	Students	48	14.91
	Military servants, government employees, and teachers	37	11.49
	Businessmen	89	27.64
	Engineers	34	10.56
	Staff in service industry	69	21.43
	Self-employed	16	4.97
	Others	29	9.01

Since passengers' opinions about feeder mode choices were collected, data were matched with relative fuzzy values corresponding to the rating from extremely important to not important at all. Moreover, the centre-of-gravity method was adopted to transfer fuzzy values into best non-fuzzy performance values (BNP) and the criteria were ranked based on the BNP. The consequences are presented in the following table (Table 6).

Table 6 – Ranking of transfer criteria

Criteria	Fuzzy weights			BNP	Ranking
	L	M	U		
In-vehicle time	0.5345	0.7739	0.9453	0.7512	3
Waiting time	0.5292	0.768	0.941	0.7461	5
Ticket-purchase time	0.4832	0.7165	0.8991	0.6996	8
Time spent in looking for parking spaces	0.4168	0.6475	0.841	0.6351	17
Transfer cost	0.4488	0.6761	0.8736	0.6661	11

Transfer promotion	0.4161	0.6463	0.8385	0.6336	18
On-time arriving	0.573	0.8233	0.9637	0.7866	1
Frequency	0.5429	0.7829	0.9509	0.7589	2
Spaces for personal belongings	0.3472	0.5693	0.7798	0.5654	19
Times of transfer	0.5239	0.7612	0.936	0.7404	7
Seat spacing	0.4404	0.6618	0.8702	0.6575	12
Convenience of using bathrooms	0.4208	0.6466	0.8432	0.6369	15
Smoothness of vehicle driving	0.468	0.6969	0.8876	0.6842	10
Injuries and deaths	0.532	0.7845	0.9093	0.7419	6
Accident occurrence	0.5357	0.7866	0.9161	0.7462	4
Personal preference for specific feeder modes	0.4329	0.6534	0.8686	0.6517	13
Transfer distance	0.4798	0.7062	0.9127	0.6996	8
Pre-trip transfer information	0.4186	0.6382	0.8534	0.6367	16
Transfer information at stations	0.4283	0.6466	0.8596	0.6448	14

Among all the mode attributes, safety has the greatest impact on respondents' transfer choices and the following attributes are convenience and quickness. A possible explanation is that safety is the basic requirement for operating transportation systems and passengers would thus pay more attention on the factors which influence the seamlessness of their trips. Consequently, on-time arriving, frequency, and in-vehicle time are the most concerned factors from a passenger's perspective.

3.1.1. Results of THSR passenger transfer demand analysis

In the passenger transfer demand analysis, the study first uses a chi-square test of independence to examine whether transfer choices are influenced by passengers' demographic background and trip characteristics. If the empirical results support that these two factors impact passengers' transfer choices, then we further conduct correspondence analysis (CA) to investigate more details on HSR passengers' transfer mode choice behavior.

3.1.1.1. Mode choices of passengers with different backgrounds

Our empirical result analysis indicates age is considered to have an impact on passengers' transfer choices and the correlation is statistically significant. Based on a test of independence, we are able to obtain: $\chi^2 = 46.682 > \chi^2_{0.05}(21) = 41.3372$, which implies that passengers' age and transfer choices are significantly related under a 5% significance level. Figures 4 represents the relationship between passengers' age and transfer choices.

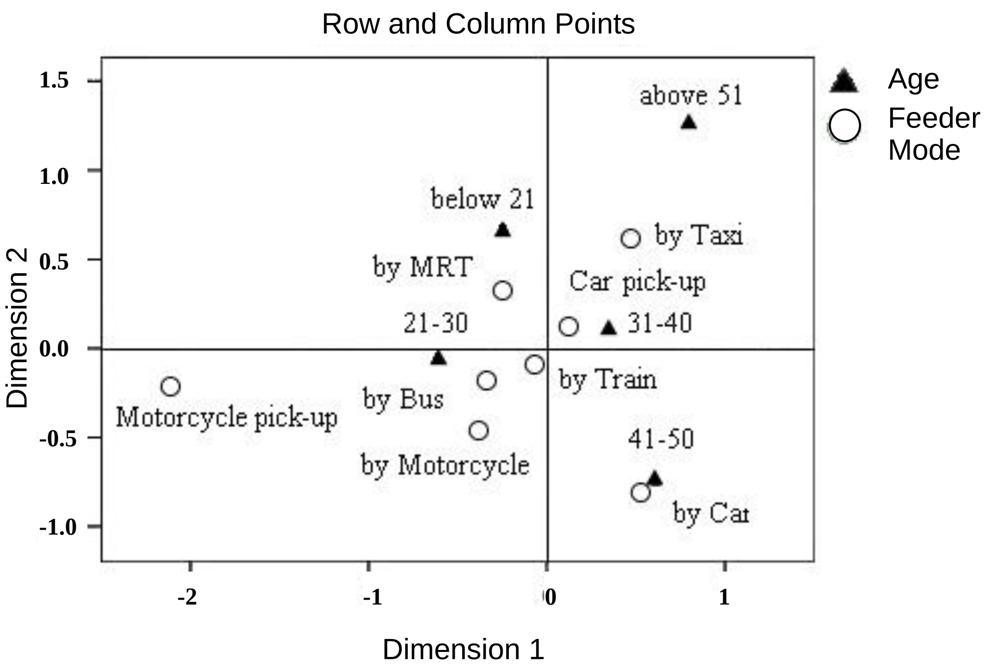

Figure 4 – Correspondence analysis plot of passengers' age and transfer choices

From the top left of Figure 4, passengers aged over 51 and 31-40 are more likely to transfer by taxis. On the bottom right of the figure, passengers aged 41-50 are more likely to choose self-driving as their feeder mode. On the left, passengers aged 21-30 generally choose MRT, bus, TRA, and car pick-up as their HSR feeder modes. In addition, passengers aged under 20 mostly transfer by MRT. Based on the above result, we find that as age grows, passengers are more likely to transfer from public transportation systems to private vehicles when choosing feeder modes. The reason could be that elder passengers want to reduce their frequency of transfer and private vehicles are able to provide seamless mobility.

This study also considers passengers' occupations on transfer mode choice. According to the test of independence, we obtain that $\chi^2 = 64.453$ and p-value=0.015 $<$ 0.05, indicating that passengers' occupations and transfer choices are significantly related under a 5% significance level. The correspondence analysis plot below represents the relationship between transfer choices and passengers' occupations.

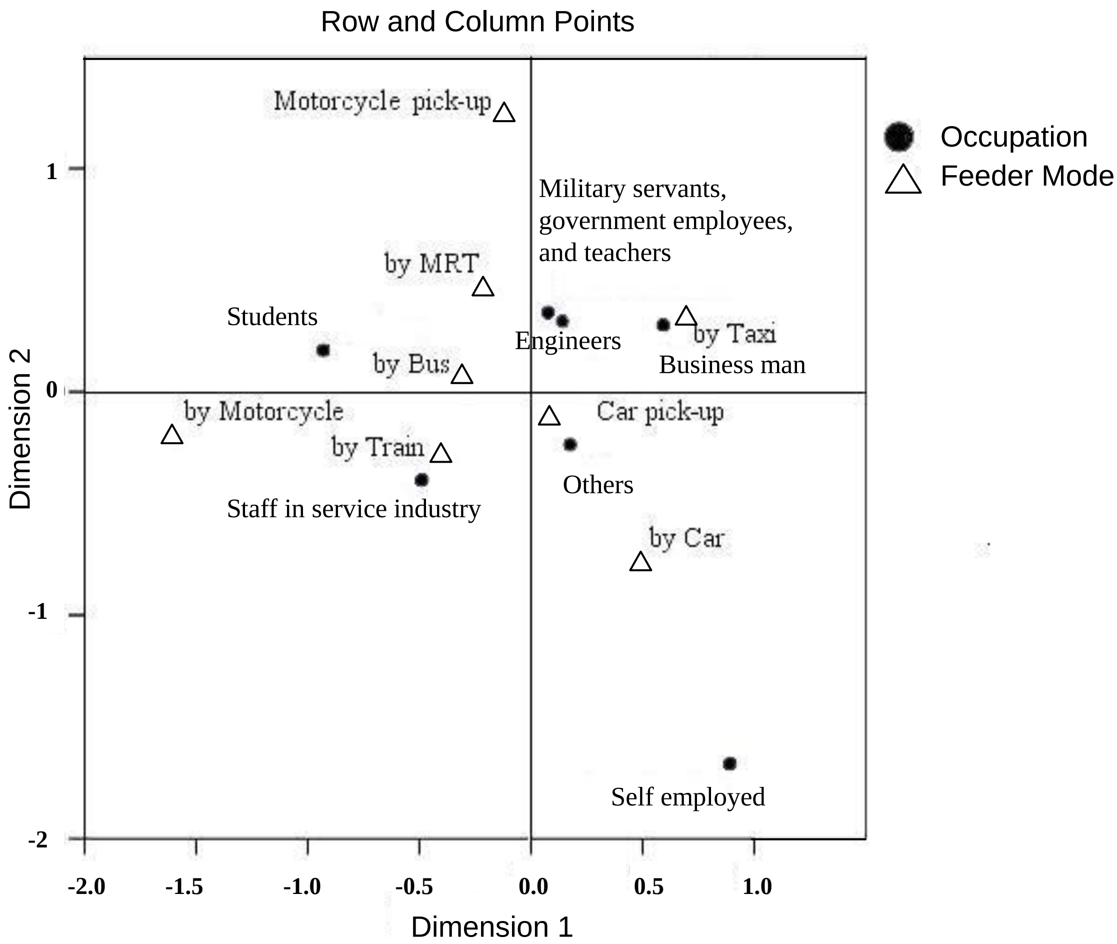

Figure 5 – Correspondence analysis plot of occupations and transit choices

Public servants, engineers, businessmen, self-employed, and passengers with other occupations are located on the right side. Taxi, self-driving, and car pick-up are also located in the same area. For self-employed, self-driving is the most frequent feeder mode for them. Businessmen choose taxis or car pick-up. Service industry employees are more likely to transfer by TRA and students commonly transfer by MRT. Public servants and engineers have similar transfer choices: MRT, taxis, and car pick-up are generally chosen by these two groups.

This study also looks at the relationship between passengers' monthly income and transfer mode choice. According to the test of independence, we are able to obtain $\chi^2 = 48.553 > \chi^2_{0.05}(21) = 32.6706$ and p-value = 0.01 < 0.05. Therefore, we find that passengers' monthly income and transfer choices are significantly related under a 5% significance level. The correspondence analysis plot below represents the relationship between transfer choices and passengers' monthly income (see Figure 6).

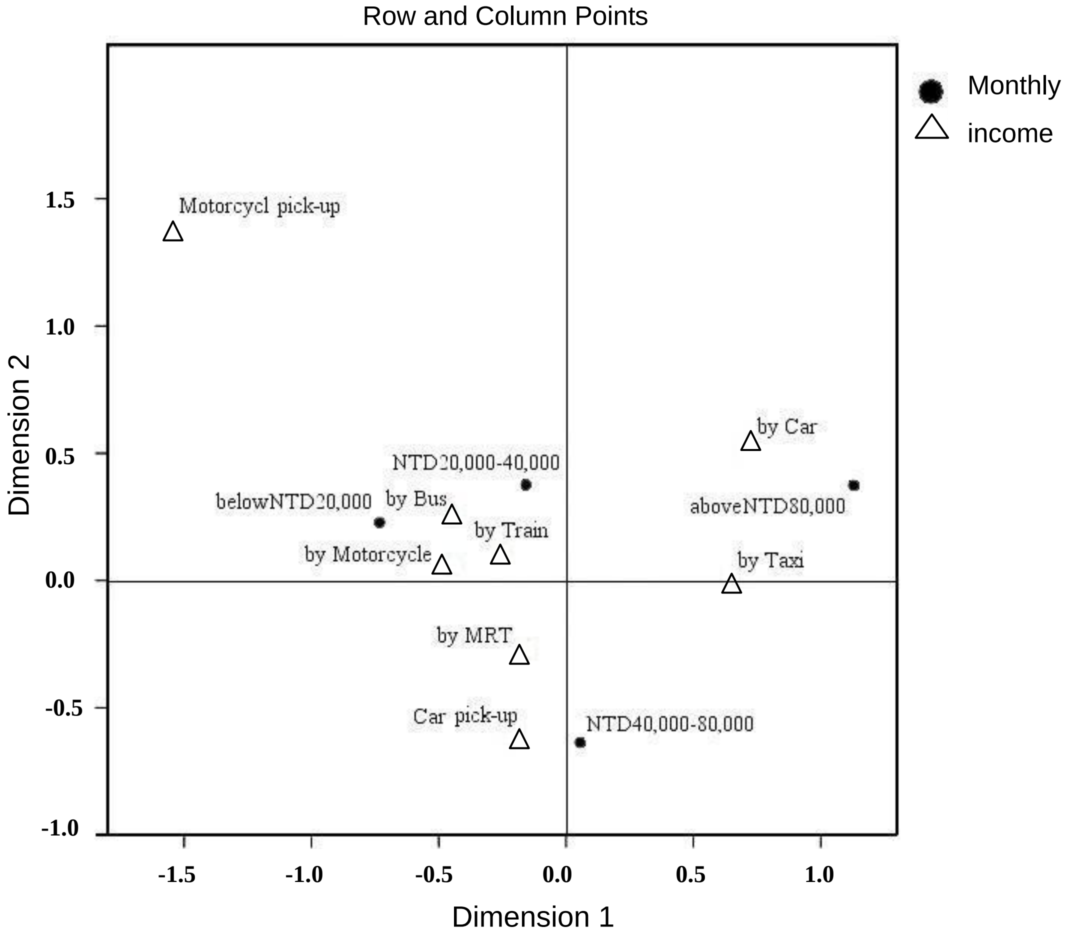

Figure 6 – Correspondence analysis plot of monthly income and transfer choices

Our finding shows passengers with higher income (over 80,000 NTD per month) generally tend to choose self-driving and taxis as their transfer choices, because they are able to afford them. On the other hand, passengers with income between 40,000-80,000 NTD are more likely to transfer by MRT or car pick-up. Passengers with income less than 20,000 NTD and those who earn 20,000-40,000 NTD per month have similar transfer choices: they are more likely to transfer by bus, TRA, MRT, and motorcycles.

3.1.1.2. Mode choices of passengers with different trip characteristics

To realize the relationship between trip characteristics and transfer choices, a correspondence analysis plot is shown below (Figure 7).

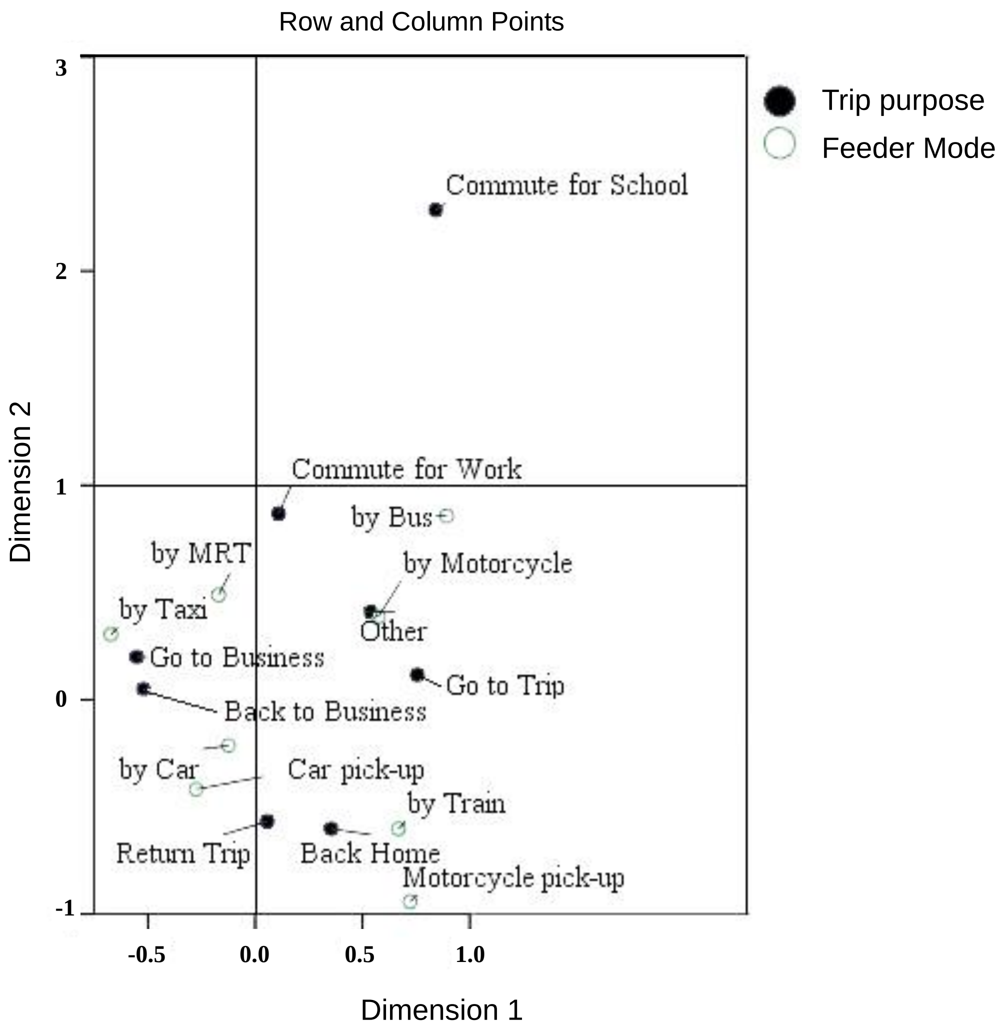

Figure 7 – Correspondence analysis plot of trip characteristics and transfer choices

In summary, passengers travelling for business purposes, both inbound and outbound journeys, are more likely to transfer by taxis. Passengers on the outbound journey of leisure trips and those who are visiting their hometown are more likely to transfer by TRA, self-driving, car pick-up, and motorcycle pick-up. For passengers who take school trips, they are the least likely to transfer by motorcycle pick-up. Instead, they probably choose to transfer by bus.

3.1.1.3. Passengers' mode choices at different types of stations

This study has defined three types of HSR stations for their transfer service provided. A test of independence was first conducted, and the overall evaluation indicates that different station types have impacts on passengers' transfer choices ($\chi^2 = 189.251$, $p - value = 0.0 < 0.05$). However, p-values obtained in each station group reveal that stations categorized in the same group are not significantly related to passengers' transfer choices. In other words, passengers at the stations categorized in the same group generally choose the same feeder mode service.

At Type I stations (i.e. Taoyuan, Hsinchu, Chiayi, and Tainan), passengers are more likely to choose self-driving and car pick-up as their transfer modes and emphasize more on convenience when choosing feeder modes. A possible reason may be public transportation systems are comparatively inconvenient at these stations and private vehicles are able to make up for such disadvantages. At Type II stations (i.e. Taichung and Zuoying (Kaohsiung)), although TRA is included in the feeder mode set, car pick-up still has the highest percentage among feeder mode alternatives. In general, passengers at Type II stations are more likely to transfer by car pick-up, TRA, taxis, and self-driving. Moreover, passengers at Type II stations tend to concern about whether the feeder modes arrive on time and total travel time, such as waiting and in-vehicle time, which implies that the TRA schedule might not match up with THSR schedule well and lead to longer waiting time. In addition, delay of TRA usually occurs during peak period and that might also result in long waiting time. At Type III stations (i.e. Taipei and Banciao), passengers are more likely to transfer by MRT and factors which influence feeder mode choices are similar to the factors mentioned above. Because the transfer system at Type III stations is a metro system, passengers might thus be more likely to emphasize the importance of on-time arriving and the frequency. In addition, due to route constraints, passengers also concern about in-vehicle time. If it takes too long to arrive destinations, passengers are likely to choose other feeder modes. Furthermore, the percentages of car pick-up and self-driving apparently decrease at Type III stations.

3.2. Data collection for panorama analysis

Because transportation system planning and urban planning require professional evaluation, we invited scholars and officials of transportation departments to fill in our expert questionnaires. The questionnaire design is based on our research evaluation framework to implement a pair-wise comparison of evaluation dimensions, factors, and alternatives, for which a pair-wise comparison matrix can be established. Finally, relative weights and evaluation toward the THSR transfer system can be derived by experts' choices.

The questionnaire contains 3 main dimensions, including passenger safety and convenience, urban planning integration, and economic issues, and 8 factors (Figure 2). Experts then assess 5 alternatives based on these dimensions and factors. A total of 32 questionnaires were distributed, and 15 valid samples were obtained. Five samples are from scholars and 10 are from officials of transportation departments.

3.2.1. Results of panorama analysis from a policy planner's perspective

Table 7 represents the relative weights of dimensions and criteria. The fuzzy weighted values of each dimension are 0.52368 (Passenger Safety and Convenience), 0.2462795 (Urban planning integration), and 0.2300389 (economic issues). Our result indicates that experts greatly emphasize "Passenger Safety and Convenience". Furthermore, the highest relative weight (0.47665) implies that safety is one of passengers' prior concerns, and experts emphasize safety as well. Therefore, when planning for THSR transfer systems, passengers' safety should be first assured.

Table 7 – Relative weights of objectives and criteria

Dimensions	factors		weight
C1 Passenger Safety and Convenience (0.52368)	C11	Convenience	0.25848
	C12	Quickness	0.26487
	C13	Safety	0.47665
C2 Urban planning integration (0.2462795)	C21	HSR station's surrounding areas renovation	0.32399
	C22	Integrating regional transportation Network	0.67601
C3 Economic issues (0.2300389)	C31	Job opportunity creation	0.29519
	C32	External cost consideration	0.37884
	C33	Increasing revenue from developing station areas	0.32597

In the dimension of "urban planning integration", the relative weights of integrating a regional transportation network equals 0.67601, which is higher than the other factor's relative weight. As a result, experts believe that integrating a transportation network in the surrounding areas of THSR stations is much more important than the HSR station's surrounding area renovation when planning for THSR transfer systems.

In regards to economic issues, the relative weight of external cost equals 0.37884. Experts indicated that properly dealing with the pollution and energy consumption brought about by transportation systems is more important than thinking about increasing job opportunities and revenue.

This study first conducted a survey on passengers' perceptions and established relative dimensions and factors based on expert and passengers' opinions, as well as, from the system's overall perspectives. Both groups hold different viewpoints on feeder mode choices. However, both passengers and experts greatly emphasize safety issues. Mentioned in the preceding paragraph, passengers place more emphasis on factors influencing trip seamlessness and convenience. On the other hand, experts and policy makers consider more on system integration and related policies.

4. CONCLUSIONS AND FUTURE RESEARCH

4.1. Conclusions

This study contributes to investigating the intermodal passenger transfer of THSR from policy planners' and passengers' perspectives. The THSR passengers' transfer mode choice preferences are examined via correspondence analysis according to various types of THSR stations. This useful information can provide practical suggestions to transport policy planners by always using a system's supply-side perspectives. The Fuzzy AHP analysis is conducted via relevant experts' opinions from the transport planners' perspectives. Therefore, this study attempts to combine two sides of perspectives to improve the THSR's feeder system service and connecting network, so as to provide useful suggestions to the central authority.

This study first investigates passengers' preferences on HSR transfer modes. The empirical results show that passengers with different genders and levels of education do not show any significant difference on their transfer mode choices. On the other hand, significant differences exist in passengers in terms of occupation and monthly income. Passengers with higher monthly income or businessmen are more likely to use private vehicles as their HSR transfer mode to avoid transferring many times to the final destination when using public transportation.

In regards to various different types of HSR stations, transfer mode usage varies from station to station. HSR Stations that include MRT and TRA services, like Taipei and Banciao stations, will attract more passenger transfers by public transportation systems and thus significantly reduce the usage of private vehicles.

The Fuzzy AHP analysis indicates passenger convenience and urban planning integration are the two most important factors for HSR passenger transfer to the final destination. Furthermore, both experts and passengers indicate that safety should be the first priority when planning the HSR transfer systems. In regards to urban planning integration and economic issues, experts believe that integrating the public transportation network while considering pollution and energy consumption in the surrounding areas is a critical factor which should be taken into serious consideration when designing the HSR's feeder system service.

The result shows most passengers tend to use private vehicles instead of public transportation, indicting that the public transportation service for HSR transfer needs to be further improved. A well-designed public transportation network is essential in order to attract passengers' usage. Therefore, the central and local authorities and HSR service providers should carefully design the HSR's feeder system network to maximize the synergies of the HSR system.

4.2. Limitations and future research

Due to time constraints and cost limitation, this study only considers passengers' egress mode choices. Future studies can combine passengers' access mode choices with the existing study to compare the details about HSR passengers' transfer behaviour preference and to derive more information on HSR's feeder system design.

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