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Longitudinal Assessment of High-speed Rail Service Delivery, Satisfaction and Operations: A Study of Taiwan and Korea Systems

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Abstract

This article compares Taiwan and Korea high speed rail systems to identify service factors that affect their long-term development. Data were collected by questionnaires and interviews administered over several years to study passenger travel behavior and perceptions of service quality. Analysis results indicate that improving operational effectiveness requires enhanced service quality and that Taiwan High Speed Rail (THSR) passengers are very concerned about facility of infrastructure services. In contrast, the main concern of Korea Train eXpress (KTX) passengers is frontline staff interaction. Notably, the data show that THSR passenger satisfaction increased steadily to levels superior to those expressed by KTX passengers. Another finding is that, in terms of resource allocation, both Taiwan and Korea should improve the handling of passenger complaints, provide improved scheduling information, and strive to improve arrival and departure punctuality. The contribution of this study is the development of a systematic method of assessing the long-term performance of high-speed rail transport services, by which management units can adjust operating strategies to continuously improve services. The analysis results can facilitate the THSR and KTX to formulating planning and operational strategies that can achieve the goal of sustainable operations.

Keywords: *high speed rail, passenger behavioral assessment, service quality, passenger satisfaction, operations management, Taiwan, South Korea, multiple-group analysis, structural equation modeling*

1. Introduction

In recent years, many countries have added high speed rail systems to their transportation infrastructure (Calvo *et al.*, 2013; Cascetta *et al.*, 2009; Chi and Javernick-Will, 2011). Rapid economic development in Taiwan has increased domestic demand for long-distance transportation for business, leisure and tourism, putting pressure on transport operators to improve service quality and operational efficiency. Highways and regular trains services are the major north-south transportation modes.

However, the highway network is heavily congested, and the rail service cannot accommodate demand. Therefore, the Taiwan High Speed Rail (THSR) began operating in 2007 to ease congestion for long-distance travel. Similarly, South Korea launched the Korea Train eXpress (KTX) in 2004 to reduce congestion on the Gyeongbu rail line, and the sustained development and construction of KTX services have become an important driver of regional economic and tourism development.

The THSR has been operating stably for more than six years. Although departures are gradually increasing, passenger occupancy rates have reached only 54.59% in 2012 which leaves considerable room for improvement (Chou and Yeh, 2013). Since its inception in 2004, KTX has continuously improved its punctuality, infrastructure facilities and service quality, and currently enjoys good profitability. However, an August, 2013 accident raised major concerns about its safety and damaged its public image. The THSR is currently operating at half capacity and is still working to improve service quality. After the Korea Train eXpress (KTX) began operations in 2004, initial feedback on traveler satisfaction indicated considerable room for improvement.

Unlike most industries, the transportation industry measures service quality by the personal characteristics of the passengers and their itineraries. Thus, the industry must clearly understand its passenger behavior and needs in order to adjust and rationalize its mode of operations to meet market demand, to attract new customers, to retain its original customer base (Lai

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and Chen, 2011), to improve customer loyalty and corporate image, and to enhance its operational performance.

In this study, Structural Equation Modeling (SEM) was used to explore key elements for improving the long-term performance of high-speed rail operation including service quality, passenger satisfaction, passenger loyalty, corporate image, and operations performance. Multi-year data (2007, 2010 and 2013) and transnational surveys were adopted to solicit and compare passenger perceptions of Taiwan and South Korea. Moreover, multiple-group analysis was used to measure model variance, and key factors were explored to determine the effects of the constructs.

The SEM analysis result was then utilized to calculate a Passenger Satisfaction Index (PSI) for an improved understanding of service satisfaction in different passengers of Taiwan and Korea groups. Finally, an importance-performance analysis was performed to evaluate resource allocation efficiency. Respective service advantages and disadvantages were also compared to provide a reference when recommending long-term improvement strategies in the future.

2. Literature Review

2.1 Review of Literature on Transport Services and Transnational Studies

Chen *et al*. (2009) developed a discrete choice model with an attitudinal variable to better understand how passengers perceived service quality in ground access mode choices to the Hong Kong International Airport (HKIA) (Chen *et al*., 2009). A structural equation model was adopted to construct a 'satisfaction' latent variable that described the causal relationship between the satisfaction latent variable and the observable variables of the trip and of the passengers.

This satisfaction latent variable was then incorporated into the discrete choice model as an additional explanatory variable. The model results indicated that passengers did consider both observed service variables and unobserved attitudinal variable for their ground access to the HKIA.

Since the public transport industry is a service industry, Jou *et al.* (2008) surveyed passengers on three major international airlines (Air China, Delta and Finnair) and found that their choice of airline mainly depends on customer perceptions of relative safety, convenience, and service quality (Jou *et al.*, 2008)

Yeh and Kuo (2003) interviewed industry insiders regarding the quality of service provided by 14 key international airports in the Asia Pacific region. A fuzzy multi-attribute decision-making model and a service efficiency index were used to compare service quality in each airport. The authors then ranked the airports according to service deficiencies and overall service quality (Yeh and Kuo, 2003).

Kuo and Jou (2014) further used structural equation modeling (SEM) to assess how service quality on direct flights between Taiwan and Shanghai affects the satisfaction, values and behavior of passengers (Kuo and Jou, 2014). They found that, out of all services offered by airlines, remedying original service defects had the greatest impact on passenger behavior.

International comparisons can reveal how national culture and socioeconomic characteristics affect operations in a particular industry. By using a comparative approach to observe the strengths and weaknesses of a given industry, operation strategies can be improved to suit particular national cultures, thus promoting the development of a successful business model.

Many industries use transnational analysis to develop strategies for improving operational performance. Askoy *et al.* (2013) studied mobile telecom service in eight countries. For example, a study of mobile telecom service in eight countries by Askoy *et al.* (2013) not only verified the impact of customer satisfaction and loyalty on operational effectiveness, but also showed that distinctive national cultural characteristics influence service expectations and thus influence customer satisfaction rates (Aksoy *et al.*, 2013).

Muller *et al.* (2003) examined how cultural differences in the United States and Ireland result in very different dining habits and very different customer expectations. They recommended that foreign firms should modify their business models to improve performance under local conditions (Mueller *et al.*, 2003). Such insights are particularly important for transnational hotel chains. For example, Yuksel *et al.* (2006) identified significant differences in the way that hotel guests from different countries express dissatisfaction, and the authors recommended actions that hotel operators can take to facilitate customer complaints and feedback (Yuksel e*t al.*, 2006).

Since Taiwan and South Korea have many geographic and social similarities, a transnational comparison of high-speed rail services between the two countries can provide useful insights that can help improve or otherwise adjust service operations to better meet passenger expectations.

2.2 Literature Support on Causal Path Assumptions

Service quality, passenger satisfaction and passenger loyalty

Service quality is defined as the customer acceptance and overall assessment of provided services (Burke *et al*., 2005), and customers' perceptions about the quality of service are heterogeneous (de Oña and de Oña, 2015). Customer satisfaction is a key service quality indicator (Eboli and Mazzulla, 2012). Lai and Chen (2011) also reported that high service quality and positive passenger perceptions are essential for high passenger satisfaction (Lai and Chen, 2011). Since service quality positively affects passenger satisfaction, we propose the following hypothesis H_1:

H_1: Service quality has a positive effect on passenger satisfaction.

Transport companies that interact effectively with their customers are likely to have high customer satisfaction. Karatepe (2006) showed that companies that have a complaint system that effectively addresses customer feedback enjoy high customer loyalty (Karatepe, 2006). Chou *et al.* (2014) demonstrated that customer satisfaction had a positive effect on customer loyalty (Chou *et al.*, 2014). This means that customers who are satisfied with the service provided by a firm are likely to have high customer loyalty and to engage in behavior with positive implications for the firm, including repeat patronage and providing unsolicited recommendations. Thus, we propose H_2:

H_2: Passenger satisfaction has a positive effect on passenger loyalty.

2.2.2 Corporate Image, Passenger Awareness and Operations

Corporate image can be defined as the customer impressions of a brand and is jointly constructed by operators and their customers. When customers receive merchandise or services from a firm, they share their experience with each other through word of mouth, which affects their impression and satisfaction with the company (Yuksel *et al.,* 2006) and re-establishes the company image. High standards of customer service and high quality products leave a good impression in the minds of customers and increase customer satisfaction. Many studies, *e.g.,* Hsu (2006), Chou and Kim (2009), Chou *et al*. (2011), and Chou and Yeh (2013), have shown that corporate image positively affects customer satisfaction (Chou and Kim, 2009; Chou *et al.,* 2011; Chou and Yeh, 2013; Hsu *et al*., 2006). Thus, we propose the following hypotheses H_3 and H_4:

H_3: Service quality has a positive effect on corporate image.
H_4: Corporate image has a positive effect on passenger satisfaction.

A strong corporate image can promote customer awareness of the goods and services provided by a firm, guide consumer decision-making and selections, and affect the operating performance of the firm. Customers tend to have greater trust and confidence in the products and services of firms with a good corporate image. Service while continuing to innovate not only creates a sense of unique identity for the company, it also helps ensure long-term customer satisfaction and loyalty, which can be translated into high margins and increased competitiveness (Yee *et al.*, 2008). Customer awareness (satisfaction and loyalty), corporate image and operating performance (*i.e.*, perceived market growth) are all related, and we thus propose the following hypotheses H_5 and H_6:

H_5: Corporate image has a positive effect on operations performance.
H_6: Passenger loyalty has a positive effect on operations performance.

3. Current Status of THSR and KTX

To alleviate the growing congestion along the north-south corridor, the Executive Yuan in Taiwan formally approved plans in 2002 to begin operating a high-speed railway in January, 2007. The proposed 345-km network with a design and operational speed of 350 km/hr and 300 km/hr respectively included stations in Taipei, Panchiao, Taoyuan, Hsinchu, Taichung, Chiayi, Tainan and Zuoying (Chi and Javernick-Will, 2011; Chou and Kim, 2009; Chou *et al*., 2011; Chou and Yeh, 2013). Construction on the new stations in Yunlin and Miaoli began in January 2013. When these two stations begin operating in 2015, the Miaoli station will be connected to the new Fungfu Station of the Taiwan Railroad Administration.

Although THSR service quality has gradually improved over time, remaining issues include night time safety, the difficulty of passenger transfers, and restrictions on the purchase of discount tickets. In 2013, fares were raised, and the network experienced power outages. The resulting delays damaged the public image of the company and highlighted the need for seamless access to other transport networks and effective crisis management.

In South Korea, the government established the Korea High Speed Rail Construction Association in 1992 to ease the worsening congestion on the Gyeongbu Expressway and rail lines by constructing a high-speed rail network. The rail network's service began in 2004 under the management of the Korean Railroad Corporation (Korail). Korail is currently running two types of high-speed trains including the KTX and the KTX-Sancheon with 330 km/h and 305 km/h at the design and top operational speeds, respectively (Korail, 2015).

The four major lines in the network are the Gyeongbu line, Honam line, Gyeongjeon line, and Jeolla line, which include 144 total stations. The train consists of 10 or 20 fixed compartments and a total of 935 seats per 20-car train, 127 first-class seats configured three to a row, and 808 economy-class seats configured four to a row. To date, the KTX service has only suffered two significant safety incidents. In 2013, a driver error resulted in a three-train collision, and in July 2011, a train fire required an emergency stop that panicked passengers. This suggests that the Korail must prioritize safety to avoid frequent incidents such as these, which will seriously damage the company image and passenger loyalty. Fig. 1 illustrates the geographical station locations for THSR and KTX.

The average THSR and KTX fares are 1.7 and 1.3 times more expensive than conventional express trains in Taiwan and South Korea, respectively. But the KTX fare level is known as very low compared to that in Japan, France, or Germany. The fares in the transportation industry are usually regulated depending on the train/seat type and travel distance. To determine the fares, THSR Corporation (THSRC) and Korail set a "minimum fare" and a "rate per km" under the government's approval, and calculates the fares using "distance scale rates" (Korail only). Outside of peak hours, both THSRC and Korail offer different and lower fares to passengers to attract high ridership at non-peak hours.

Moreover, just like the THSRC designates special discounts and free seats in several standard cars, Korail has developed marketing strategies by taking into account multiple factors such as seat direction (about half of the seats are positioned in backward), time (morning or evening), and day type (weekday or weekend) (Korail, 2004). Notably, many Korean passengers experience discomfort when using the backward seating, allegedly due to cultural differences. Because of low demand for those seats, Korail has partially repositioned them to face forward to

Fig. 1. THSR and KTX Station Locations

accommodate customer preference, but reverse-direction seats still exist. With no surprise, a passenger can book tickets in advance using the online ticketing system and mobile app as well as at the THSR or KTX stations.

Although THSR and KTX encountered some technical difficulties and minor delays during their early operation phases, both of them have a reputation for good service overall. Particularly, compared to highway travel it is nearly three times faster in terms of the travel time. Also, it usually connects at most of the stations that are located in the centers of the cities thereby providing more convenience for travelers compared to airports, which are located outside of cities. But there are still passengers' concerns, such as ride comfort while passing through tunnels or over bridges, inconsistent speed due to the mountainous topography of Taiwan and South Korea, insufficient leg-room in KTX economy-class, and higher fares as compared to other forms of transports.

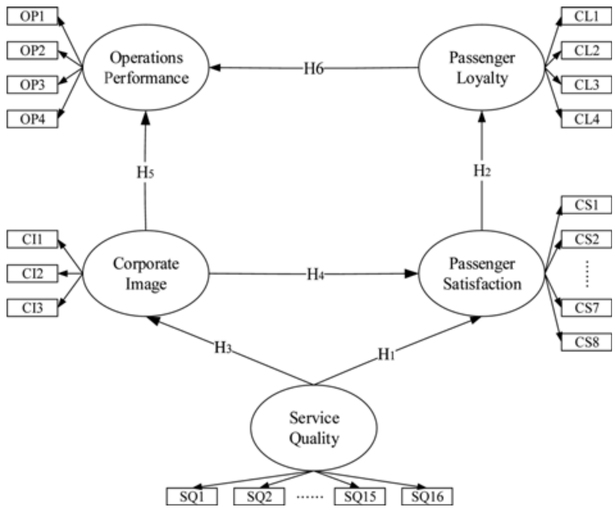

Fig. 2. Research Model in 2013

4.1 Research Methodology

Based on our review of the above literature, we propose an updated model (Fig. 2) for construct causality assumptions and related measurements from the relevant literature (Table 1). Data collection was performed by a questionnaire survey and interviews of THSR passengers. First, structural equation modeling and multi-group analysis were used to optimize the models for Taiwan and South Korea and to obtain the weightings for each dimension and the dimensional path coefficients. Based on these results and on prior data reported in the literature (Chou and Kim, 2009; Chou *et al*., 2011; Chou and Yeh, 2013), passenger satisfaction and operational performance trends over time were compared between the two systems.

4.1 Structural Equation Modeling

Structural Equation Modeling (SEM), which was first proposed by Jöreskog (1973), combines the characteristics of path analysis, confirmatory factor analysis and structural regression models. The SEM is used in many fields, including social sciences (Chou

Table 1. Construct and Measurement Variable Definitions Obtained from the Literature

Research construct	Sub-category	Construct measurement variable	Reference
Service Quality	Comfort of service	(SQ1) The air conditioning in the carriages is comfortable. (SQ2) The noise level in the carriage is comfortable. (SQ3) The high speed rail (HSR) service staff always provide services in a pleasant manner. (SQ4) The HSR service staff provides additional services when requested.	(Eboli and Mazzulla, 2012)
	Overall environment	(SQ5) Seats in the carriage are spacious, comfortable, and clean. (SQ6) The directional signs at the station are easy to understand. (SQ7) The cleanliness level of the stations.	(Eboli and Mazzulla, 2012; Givoni abd Rietveld, 2007)
	Convenience	(SQ8) The stations are in convenient locations (SQ9) Transfer services are convenient (SQ10) Scheduling information is easily available	(Brons *et al.*, 2009; Cheng, 2010; Chou and Yeh, 2013; Eboli and Mazzulla, 2012; Givoni abd Rietveld, 2007)
	Response ability	(SQ11) The HSR provides information to customers quickly and accurately. (SQ12) The HSR rapidly and efficiently responds to customer questions. (SQ13) The HSR has multiple complaint channels.	(Eboli and Mazzulla, 2012)
	Ticketing service	(SQ14) Ticket machines are easy to use. (SQ15) Booking channels are diverse and easily accessible (*e.g.*, convenience stores, internet booking, and phone). (SQ16) Staff of the HSR ticketing service company have a friendly attitude.	(Cheng, 2010; Chou and Yeh, 2013; Eboli and Mazzulla, 2012)
Passenger Satisfaction		(CS1) The HSR is an efficient transportation system. (CS2) Passengers feel comfortable and safe when using the HSR. (CS3) The HSR provides services that meet customer expectations and requirements. (CS4) The HSR tickets are reasonably priced. (CS5) The HSR handles customer complaints appropriately. (CS6) I believe that the HSR has satisfactory complaint processing procedures. (CS7) The HSR listens to and accepts customer complaints in an open-minded manner. (CS8) The HSR responds to customer complaints by making improvements.	(Eboli and Mazzulla, 2012; Jou *et al.*, 2008; Karatepe, 2006; Yuksel *et al.*, 2006)
Passenger Loyalty		(CL1) The HSR encourages customers to make suggestions for improvement. (CL2) I will use the HSR the next time I travel. (CL3) If there is an opportunity, I will actively recommend the HSR to my family and friends. (CL4) Despite an increase in the HSR ticket prices, I am still willing to use the HSR.	(Aksoy *et al.*, 2013; Lai and Chen, 2011; Yee, Yeung *et al.*, 2010)
Corporate Image		(CI1) The HSR departures and arrivals are punctual. (CI2) The HSR has a convenient service schedule. (CI3) The HSR has a positive corporate image.	(Chou and Kim, 2009; Yee *et al.*, 2010)
Operations Performance (Perceived market growth)	Financial condition	(OP1) The HSR operating growth rate has increased significantly. (OP2) The HSR profit rate has already increased significantly	(Chou and Yeh, 2013)
	Innovation and development	(OP3) The HSR develops new markets continuously. (OP4) The HSR values the latent after-sales requirements of customers.	(Sadikoglu and Zehir, 2010)

and Yeh, 2013), behavioral sciences (Yuksel *et al.*, 2006), and psychology (Meuleman *et al.*, 2009), to identify construct relationships that cannot be directly observed.

In SEM, factor analysis variables must be mutually independent and observed variables can only be used to predict a single latent variable. An improved path analysis cannot be used to estimate error and thus increases analysis accuracy. The core concept of SEM is the use of analysis of covariance to minimize the gap between the population covariance matrix and sample covariance (Byrne, 2013).

The SEM combines a measurement model and a structural model. The measurement model presents a linear relationship between indicators and constructs, and the constructs can be explained by the extent of the indicator definitions. The structural model, which establishes a linear regression between established constructs, can be used for simultaneously evaluating system test problems and causal relationships with minimal measurement errors.

4.1.1 Reliability Analysis

Reliability is tested to estimate the degree of error (Kline, 2011). Small degrees of error indicate highly reliable test results. Chronbach α is used to determine internal consistency in tests with multiple scores, where a score of 0.5 or above indicates high reliability and 0.7 or above is ideal (Hair *et al.*, 2009).

Another measure of reliability is Composite Reliability (CR), which accounts for the standardized factor loading of the measurement error for each indicator. Internal consistency is measured by CR, for which a score of 0.6 or above indicates appropriate construct reliability (Fornell and Larcker, 1981).

4.1.2 Validity Analysis

Validity refers to whether the measurement actually approximates the desired properties of the object in question (Chou and Yeh, 2013). In social and behavioral sciences, construct validity is extremely important for determining the validity of measurement tools that use multiple indicators (Kline, 2011).

Construct validity can be categorized as convergent validity and discriminant validity. A high factor loading suggests that a construct indicator has high convergent validity. The Average Variance Extracted (AVE) for the indicators of the same construct provides explanatory power for average variation in a construct. For sufficient convergent validity, Fornell and Larcker (1981) recommended that the AVE should be at least 0.5 (Fornell and Larcker, 1981).

In contrast, discriminant validity is defined as a low correlation between two measured constructs (Chou and Yeh, 2013); in this case, all constructs are examined to meet discriminant validity.

4.1.3 Multiple-Group Analysis

Multiple-group analysis is used in SEM to test whether the same hypothetical model can be adapted for different sample groups. Since equivalency cannot be established between samples taken from different countries and time periods, and since various interpretations of indicator results may cause systemic errors (Meuleman *et al*., 2009), multiple-group analysis is needed to improve estimation accuracy when applying a model in different sample groups.

The three measures of invariance are configural invariance used to establish groups using the same structural model; metric invariance used to determine the generalizability of questionnaire surveys, and scalar invariance used to determine whether the average of latent variables differs across groups.

4.2 Passenger Satisfaction Index

The Passenger Satisfaction Index (PSI) developed by Chou *et al*. (2011) (Chou *et al*., 2011), which is based on the American Customer Satisfaction Index (ACSI), is used to compare passenger satisfaction with high speed rail services in two different countries over a given time period. The ACSI is calculated as follows (Anderson and Fornell, 2000):

$$\mathrm{ACSI}=\frac{E[\xi]-\mathrm{Min}[\xi]}{\mathrm{Max}[\xi]-\mathrm{Min}[\xi]}\times 100 \tag{1}$$

where ξ, E[.], Max[.] and Min[.] are the latent variable, the expected value, the maximum value, and the minimum value, respectively, for overall customer satisfaction. The maximum and minimum values are calculated as follows:

$$\mathrm{Max}[\xi]=\sum_{i=1}^{n} W_i \mathrm{Max}[\mathbf{Y}_i] \tag{2}$$

$$\mathrm{Min}[\xi]=\sum_{i=1}^{n} W_i \mathrm{Min}[\mathbf{Y}_i] \tag{3}$$

where Y_i is the observed variable for potential passenger satisfaction and W_i is the weighting.

The PSI is calculated as follows:

$$\mathrm{PSI}=\frac{\sum_{i=1}^{n} W_i \overline{Y}_i-\sum_{i=1}^{n} W_i}{(r-1)\times\sum_{i=1}^{n} W_i}\times 100 \tag{4}$$

where $\overline{Y}_i$ is the average number of passenger satisfaction indicators, W_i is the indicator weight, and r is the scale measure of the questionnaire. The PSI ranges from 0-100, and a high PSI indicates high passenger satisfaction.

4.3 Importance-Performance Analysis

Importance-performance analysis simply and clearly presents advantages and disadvantages of operation and distinguishes between valued service factors. Operating units use importance-performance analysis to optimize their allocation of resources. Therefore, importance-performance analysis is frequently used to develop product and service strategies in service industry management, including hotel management and public transport services (Chen, 2014; Chou *et al.*, 2011; Geng and Chu, 2012).

For a clear and simple presentation of the importance and expressiveness of performance-related impact factors, and to determine whether resources are appropriately allocated, all factors are divided into four quadrants (Fig. 3). The first quadrant includes factors with high importance and high expressiveness. This quadrant indicates the appropriate resource allocation; the second quadrant includes high-importance but low-expressiveness factors, which should receive increased attention and resources; the third quadrant includes factors with low importance and low expressiveness. For these factors, input costs should be minimized to improve performance; the fourth quadrant includes factors that have high expressiveness and low importance and are potentially over-resourced.

Generally, the vertical axis indicates the importance while the horizontal axis indicates the expressiveness performance. For a clear depiction of passenger perceptions of high-speed rail service quality and for a clear understanding of the key factors in operational effectiveness, corporate image and passenger loyalty, this study redefined the horizontal axis as customer recognition (perception) to create an importance-recognition/perception analysis.

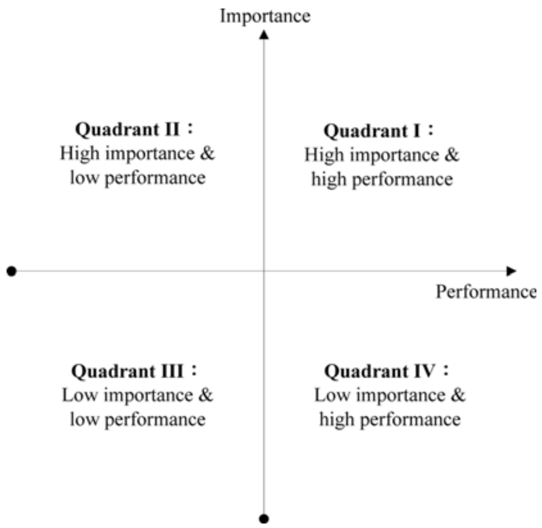

Fig. 3. Importance–Performance Matrix

5. Survey Data and Model Development

5.1 Research Targets and Sampling Method

All questionnaire items and all constructs were adapted from the related literature, including items measuring for service quality, passenger satisfaction, passenger loyalty, corporate image and operational performance. All items were measured using a Likert scale from 1 (“very dissatisfied/strongly disagree”) to 7 (“very satisfied/strongly agree”).

The questionnaire survey targeted passengers who had previously used high-speed rail services in Taiwan or South Korea. Researchers administered the questionnaire at THSR stations in Taipei, Taichung and Kaohsiung. The number of samples was determined by convenience random sampling measures as follows:

$$n = \frac{Z^2 p(1-p)N}{e^2(N-1) + Z^2 p(1-p)} \quad (5)$$

where n is the number of samples, N is the population number, e is the allowable error, Z is the standard normal value at a 95% confidence level, and p is the prevalence of the forecast population group.

Data collection was performed on weekdays from 10 am to 7 pm during May - August 2013 at THSR and KTX stations. Data for the HSR users sampled in Chou and Kim (2009) (Chou and Kim, 2009) and in Chou and Yeh (2013) (Chou and Yeh, 2013) were also used for further longitudinal comparison and exploration. Table 2 shows the results for the 2007, 2010 and 2013 surveys.

5.2 Data Characteristics

Table 3 compares the socioeconomic data for the Taiwan and Korea samples. Most subjects in the Taiwan sample group were aged 19-39 years, and most were college graduates, which suggests that THSR riders are disproportionately young and well-educated. Most respondents were either students or workers in the commercial or service sectors, which suggests that THSR services are mainly used to reduce commuting and business travel times.

Notably, the THSR was still offering discount fares to attract riders during the data collection period. Therefore, the number of students and homemakers in the sample may have been higher than usual. Respondents were generally reluctant to indicate personal monthly

Table 2. Survey Data for Both Countries for Each Year

Country	Taiwan*			Total	Korea*			Total
Year	2007	2010	2013		2007	2010	2013	
Questionnaires distributed	460	310	250	1020	430	230	232	892
Returned questionnaires	418	292	204	914	414	200	201	815
Response rate	90.90%	94.20%	81.60%	89.61%	96.30%	87.00%	86.60%	98.31%
Confidence level	95%			-	95%			-
Allowable error	±0.022	±0.027	±0.030	-	±0.023	±0.031	±0.031	-
p value	0.5			-	0.5			-

*2007 data obtained from Chou and Kim (2009) (Chou and Kim, 2009) and Chou *et al.* (2011) (Chou *et al*., 2011); 2010 data obtained from Chou and Yeh (2013) (Chou and Yeh, 2013); 2013 data collected by the authors.

Table 3. Socioeconomic Characteristics of Passengers

Country		Taiwan						Korea					
Year		2007		2010		2013		2007		2010		2013	
Item		Distribu-tion	Percent-age (%)	Distribu-tion	Percent-age (%)	Distribu-tion	Percent-age (%)	Distribu-tion	Percent-age (%)	Distribu-tion	Percent-age (%)	Distribu-tion	Percent-age (%)
Gender	Male	199	47.6	151	51.7	92	45.1	142	34.3	107	53.5	100	49.8
	Female	219	52.4	141	48.3	112	54.9	272	65.7	93	46.5	101	50.2
Age	18 years and below	0	0	12	4.1	14	6.9	0	0	7	3.5	24	11.9
	19 to 25 years	72	17.2	67	22.9	76	37.3	85	20.5	53	26.5	103	51.2
	26 to 32 years	144	34.4	46	15.8	47	23	241	58.2	72	36	41	20.4
	33 to 39 years	110	26.3	65	22.3	30	14.7	32	8.5	29	14.5	9	4.5
	40 to 46 years	55	13.2	39	13.4	15	7.4	20	4.8	20	10	9	4.5
	47 to 53 years	28	6.7	28	9.6	11	5.4	22	5.3	9	4.5	5	2.5
	54 to 60 years	9	2.2	23	7.9	5	2.5	11	2.7	6	3	6	3
	61 years and above			12	4.1	6	2.9			4	2	4	2
Education level	Elementary school and below	0	0	2	0.7	1	0.5	0	0	1	0.5	4	2
	Junior high school	6	1.4	30	10.3	5	2.5	5	1.2	1	0.5	12	6
	Senior high school or vocational school	36	8.6	56	19.2	26	12.7	34	8.2	16	8	98	48.8
	University and college	264	63.2	138	47.3	126	61.8	33.7	81.4	142	71	73	36.3
	Graduate institute and higher	112	26.8	66	22.6	46	22.5	38	9.2	40	20	14	7

Table 3. (continued)

Country		Taiwan						Korea					
Year		2007		2010		2013		2007		2010		2013	
Item		Distribution	Percentage (%)	Distribution	Percentage (%)	Distribution	Percentage (%)	Distribution	Percentage (%)	Distribution	Percentage (%)	Distribution	Percentage (%)
Career	Student	104	24.9	45	15.4	78	38.2	199	48.1	45	22.5	138	68.7
	Commercial and service industries	156	37.3	75	25.7	48	23.5	54	13	51	25.5	21	10.4
	Industrial and manufacturing industries	60	14.4	49	16.8	15	7.4	12	2.9	19	9.5	2	1
	Soldiers, public servants, and teachers	52	12.4	38	13	24	11.8	50	12.1	11	5.5	4	2
	Home caretakers	9	2.2	23	7.9	9	4.4	12	2.9	10	5	8	4
	Agricultural, forestry, fishery, husbandry, and mining industries	-	-	16	5.5	1	0.5	N/A	N/A	4	2	0	0
	Freelancer	23	5.5	17	5.8	12	5.9	16	3.9	11	5.5	9	4.5
	Retired people	4	1	14	4.8	2	1	15	3.6	6	3	0	0
	Others	10	2.4	15	5.1	15	7.4	56	13.5	43	21.5	19	9.5
Average monthly income (US$)	0~500	104	24.8	82	28.1	83	40.7	131	31.6	44	22	118	58.7
	501~1,000	96	23	45	15.4	26	12.7	74	17.9	4	2	26	12.9
	1,001~2,000	110	26.4	89	30.5	57	27.9	75	18.1	50	25	22	10.9
	2,001~3,000	49	11.7	51	17.5	26	12.7	50	12.1	48	24	15	7.5
	3,001 and above	59	14.1	25	8.6	12	5.9	84	20.2	54	27	20	10

income. Overall, a multi-year comparison showed no large changes in the socioeconomic distribution of the passengers. The THSR is still assessing service areas that need improvement as it attempts to improve occupancy rates in all passenger groups.

The 2007-2010 data for KTX passengers also revealed a high concentration of young riders (19 to 39 years old), most of whom were college graduates. However, the 2013 survey showed that the number of passengers with a high school education was 40.8% higher than those in years 2007 and 2010. It indicates that passengers were not limited to highly educated groups. Convenience sampling revealed a preponderance of students and commercial and service sector workers, which indicates that KTX is an emerging transportation mode for students and commuters seeking to reduce travel time.

The results of statistical analyses suggest that monthly personal income does not directly affect intention to use KTX, and the 2013 survey results indicated that 58.7% of passengers had an average monthly personal income lower than US$500, indicating that the ridership is skewed toward younger passengers. Most passengers were reluctant to divulge income information.

5.3 Transnational Modeling

5.3.1 Model Tuning

The reliability of inter-group analysis was increased by using SEM multiple-group analysis to develop the best transnational model for the two countries as a basis for comparison and discussion. The structure of the questionnaire and hypothetical model were developed after repeated testing and modification to develop a model for confirmatory factor analysis invariance and structural invariance.

With confirmed validity, the factor loadings represent the extent to which the measurement variables can explain variability. Since a factor loading greater than 0.5 is interpreted as adequate explanatory power (Hair *et al.*, 2009), factor loadings below 0.5 were discarded. A standard residual error of +3 indicates an insufficient estimated variation or covariate of a variable while a standard residual error size below -3 indicates excessive interpretation (Byrne, 2013). Therefore, individual items with an absolute residual value lower than 3 were continuously deleted.

5.3.2 Multi-Group Confirmatory Factor Analysis

Multi-group confirmatory factor analysis is an effective means of evaluating measurement invariance (Hansen *et al.*, 2011). The representative of variables is determined by releasing the fixed estimates for factor loadings for all variables in the model one at a time and then comparing them with those in the free estimation model. Based on the measurement results, the indicators Climate Comfort (SQ1), Sense of Security (CS2), Intention to Ride Again (CL2), Goodwill (CI3) and Continued Development of New Markets (Operating Stations) (OP3) required the smallest increase in chi-square values after explanation. Thus, a factor loading of 1 was selected for representative variables. The factor loadings for other variables were not fixed in simultaneous analysis of the Taiwan and Korea models.

Table 4 shows most common means of detecting goodness of fit test, which include the chi-square degrees of freedom, Comparative Fit Index (CFI), and root mean square error of approximation (RMSEA). (Chathoth *et al.*, 2011; Costa-Font and Gil, 2009; Hansen *et al.*, 2011). Notably, the goodness of fit before and after setting the invariance for the model in this study indicated a good fit between the invariant model and sample.

6. Empirical Analysis and Management Implications

For a clear comparison of representative impact indicators for

Table 4. Goodness-of-Fit Testing in Multi-Group Analysis

Fit index	Value	Measures of invariance	Suggested requirement standard	Description
χ^2/df	3.541	1.923	1 - 5	Chi-square degrees of freedom considering the impact of estimated parameters on degrees of freedom and the impact of the sample quantity on the chi-square value; values below 2 indicate good fitness.
AGFI	0.92	-	> 0.9	AFGI system using degrees of freedom and number of variables to improve GFI, where improved GFI is impacted by the shortcomings of the units; values of 0.9 or above indicate good fit.
CFI	0.958	0.932	> 0.9	The CFI measurement of improvement in the non-centralized parameter between a limited model and a non-saturated model; values of 0.9 or above indicate good fit.
PNFI	0.788	-	> 0.5	The PNFI considering the degrees of freedom; values of 0.5 or above indicates a highly simplified model.
RMSEA	0.053	0.032	< 0.08	The RMSEA estimate of the difference between the average sample covariance matrix and the parent covariance matrix in each degree of freedom. The RMSEA is relatively unaffected by the number of samples; 0.08 or below indicates a good result.
NNFI	-	0.92	> 0.9	The NNFI is a non-standardized relative indicator that reflects the difference between the hypothetical model and the independent model. The NNFI is commonly used to compare two or more opposing model.
AIC	-	1475.93	Below saturation mode and independent mode	The AIC values are similar to PNFI and provide a simple model for determining the degree of precision. The AIC streamlines comparisons of multiple models; (saturation model: 1520.0, independent model: 8685.27).

Taiwan and Korea, this study separately analyzed the differences between the two countries in terms of change over time and quantified changes to passenger perception of high speed rail service quality over time to identify differences between the cultural environments of the two countries that could result in differences in the extent to which these service differences impact operating performance over the long term.

6.1 Causal Path Results

This section describes the causal path analysis of the samples for 2007, 2010 and 2013 to explore the extent of causal impact between each construct. The path assumptions model proposed by Chou and Kim (2009) was used to survey the service perceptions and satisfaction of high-speed rail passengers in Taiwan and Korea before 2007 (Chou and Kim, 2009; Chou *et al.,* 2011). For a clear understanding of the interaction between passenger perceptions and operational performance, operational performance constructs are added to the hypothetical model for 2010 (Chou and Yeh, 2013). Since a literature review also showed that passenger complaints result from unsatisfactory service (Szymanski and Henard, 2001), so passenger complaints were combined with relevant indicators for a reanalysis of passenger satisfaction construct.

The analysis results (Fig. 4) show that, for both KTX and THSR, service quality has a significant positive impact on corporate image, which plays a mediating role between passenger satisfaction and passenger loyalty. Another finding is that operational performance is based on corporate image and passenger loyalty. Therefore, to achieve high operational performance, high-speed rail service providers should commit to improving service

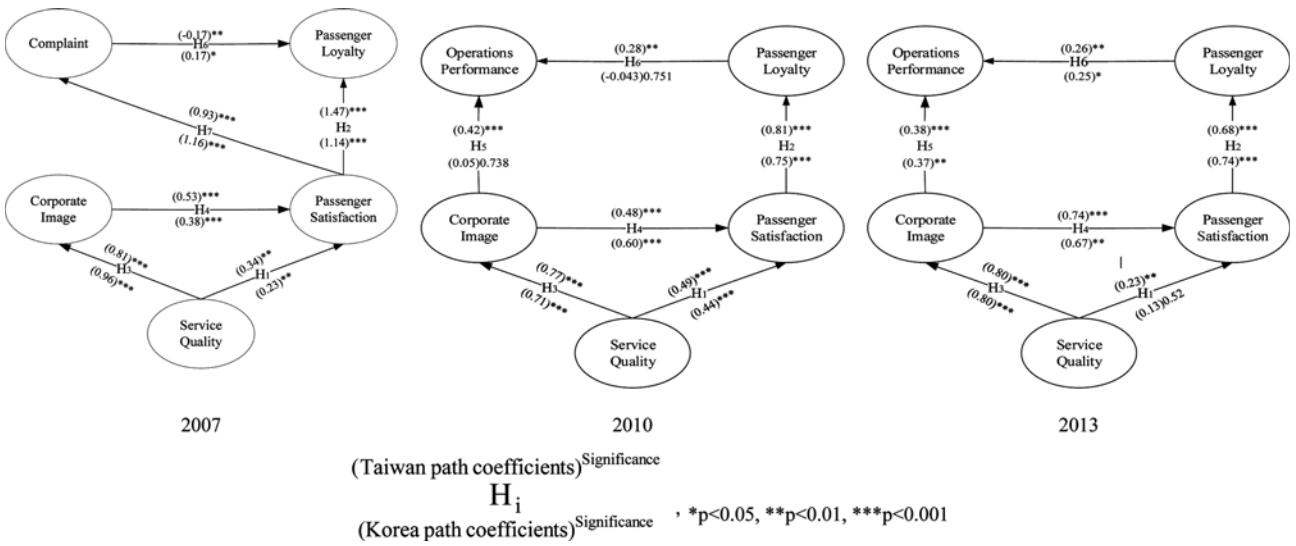

Fig. 4. Construct Paths for Taiwan and Korea

quality in order to establish a positive corporate image, which simultaneously improves customer satisfaction and loyalty.

During 2007-2013, the Taiwan service quality constructs had statistically significant direct positive effects on corporate image. Thus, THSR can shape passenger perceptions by offering high service quality. Compared to service quality, corporate image has a larger direct overall impact on passenger satisfaction. Corporate image plays a mediating role between service quality and passenger satisfaction. Therefore, the total impact of service quality on passenger satisfaction is larger than that of corporate image. Therefore, improved passenger satisfaction requires improved service quality, which simultaneously helps to establish a positive corporate image.

As expected, the THSR analysis results showed that passenger satisfaction has a significant positive impact on passenger loyalty. Thus, we established that passenger loyalty depends on whether operating units effectively maintain passenger satisfaction. Compared to passenger loyalty, corporate image has significantly larger direct impacts and overall impacts on operating performance. Therefore, efforts to improve operational performance should focus on providing high quality service to establish a good corporate image, which indirectly enhances passenger satisfaction and loyalty.

The analysis results for KTX also showed that service quality has a significant positive correlation with corporate image. Therefore, the corporate image of high speed rail service providers is highly dependent on service quality. This validated result indicates that the impact of service quality on corporate image is not affected by national context. The analysis results show that, over time, the partial mediating role of corporate image on the impact of service quality on passenger satisfaction changes to a total mediating role. This indicates that the corporate image has already been established by achieving high satisfaction in KTX passengers through high service quality. Thus, KTX should focus on providing high service quality in order to maintain its positive corporate image.

For both KTX and THSR, high passenger loyalty can only be established by maintaining high customer satisfaction. Although, compared to passenger loyalty, corporate image has larger direct and total impacts on operational performance, both corporate image and passenger loyalty significantly affect operational performance each year. Therefore, both corporate image and passenger loyalty are key prerequisites for improving operational performance, and both are based on excellent service quality.

6.2 Passenger Behavioral Assessment Indicators

Transnational and cross-time analyses were utilized to assess passenger behavior in Taiwan and Korea. The standardized factor loading of the measurement error for each indicator is accounted by Composite Reliability (CR). CR ranges from 0 to 1 and a CR score of 0.6 or above indicates construct reliability.

6.2.1 Transnational Analysis

The overall average factor loadings over 3-year period of the study (Fig. 5) show that the passenger behavioral assessment indicators for THSR are superior to those for KTX. In the service quality dimension, THSR had high scores for SQ5 Seat Comfort (0.78), SQ7 Station Cleanliness (0.76), SQ1 Comfortable Air Conditioning (0.72), and SQ6 Station Layout (0.70). Representative indicators for KTX service quality include SQ12 Quick Response to Inquiries (0.67), followed by SQ10 Ease of Obtaining Schedule Information (0.65) and SQ13 Multiple Complaint Channels (0.65). These results indicate that THSR emphasizes hardware quality while KTX emphasizes high quality interaction between the corporation and its passengers.

In terms of passenger satisfaction, both THSR and KTX had

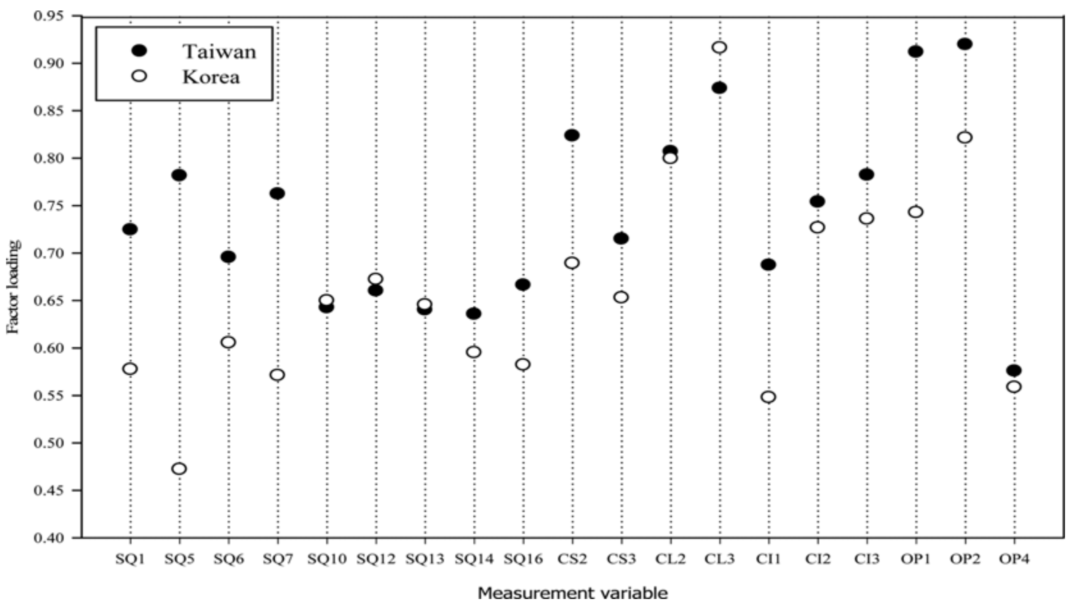

Fig. 5. Average Impact Weighting for Assessed Indicators

high scores for CS2 Sense of Safety (0.85 and 0.69, respectively). Analysis results clearly indicate that CS2 showed high explanatory power for passenger satisfaction. The THSR scored 0.71 for indicator CS3 (Services Meet Expectations); passengers indicated that THSR fares are considerably more expensive than those for other forms of public transport. They thus had higher expectations of service quality. For both countries, analysis results for the passenger loyalty dimension showed that indicator CL3 (Intention to Recommend) had very high factor loadings (0.87 and 0.92), which indicate that it was a very good indicator of this dimension. The results for CL2 (Intention to Ride Again) for THSR and KTX (0.81 and 0.80, respectively) also showed that both systems commanded high explanatory variance of passenger loyalty.

Analysis results for corporate image showed that indicator CI3 Goodwill (0.78 and 0.74) had relatively high factor loadings, which indicates that Goodwill highly explained advertising, and onsite service atmosphere. The next highest factor loading is found in CI2 Schedule Meets My Needs (0.75 and 0.73), indicating that this indicator explained a large proportion of punctuality. Therefore, when operators satisfactorily meet the needs of the public, dependence on the high-speed rail increases. From the passenger perspective, the best indicators of operating performance are OP2 Increased Profitability (0.92 and 0.82) and OP1 Increased Revenue (0.91 and 0.74).

The THSR has not been in service as long as KTX. Therefore, THSR passengers are more concerned about service quality and also have relatively higher service expectations. In terms of service quality, THSR passengers are relatively more concerned with facility of infrastructure services while KTX passengers are most concerned about the quality of interaction with company personnel. Therefore, THSR should ensure regular hardware testing and maintenance while KTX should improve staff training. In terms of passenger satisfaction, passengers in both countries were highly concerned with safety. Given its recent history of accidents, KTX should improve train maintenance and safety testing. The analytical results suggest that, in both Taiwanese and Korean cultures, customer loyalty is expressed passively, and loyal customers engage in quiet support rather than by actively making complaints or suggestions.

6.2.2 Cross-Time Analysis

The analysis results in Table 5 show that most measured indicators of THSR are highly reliable (greater 0.6). Most indicators of passenger satisfaction, passenger loyalty, corporate image, and operations performance increased during 2010-2013. Compared to THSR, more factor loadings of KTX are lower 0.6 and more indicators decreased during 2010-2013.

During 2007-2013, the SQ1 (Comfortable Air Conditioning) factor loadings for THSR consistently exceeded 0.7 (Table 5). Since Taiwan is a subtropical country with hot summers, passengers demand efficient air conditioning. From a low in 2007, the value for SQ6 (Arrangements for Moving Lines) increased in years 2010 and 2013, and the number of departures tended to increase with the number of passengers, especially during peak travel times such as national holidays. Therefore, operating authorities must regularly review line and station arrangements and must determine whether future lines can accommodate peak traffic.

Table 5. Factor Loadings for Invariance Model

Construct	Measurement variable	Factor loading							
		Taiwan				Korea			
		2007	2010	2013	Average	2007	2010	2013	Average
Service Quality	(SQ1) Comfortable air conditioning	0.71	0.75	0.71	0.72	0.63	0.59	0.52	0.58
	(SQ5) Comfortable and clean seats	0.77	0.82	0.76	0.78	0.54	0.49	0.38	0.47
	(SQ6) Understandable directional arrangements	0.66	0.73	0.7	0.70	0.66	0.51	0.65	0.61
	(SQ7) Cleanness	N/A	0.76	0.76	0.76	N/A	0.59	0.55	0.57
	(SQ10) Easily available scheduling information	0.75	0.58	0.6	0.64	0.58	0.71	0.66	0.65
	(SQ12) Rapid response to customer questions	0.75	0.59	0.64	0.66	0.72	0.64	0.66	0.67
	(SQ13) Multiple complaint channels	0.73	0.57	0.62	0.64	0.67	0.61	0.66	0.65
	(SQ14) Accessible ticket machine services	N/A	0.61	0.66	0.64	N/A	0.66	0.53	0.60
	(SQ16) Amicable service staff	N/A	0.69	0.64	0.67	N/A	0.58	0.58	0.58
Passenger Satisfaction	(CS2) Customers feel comfortable and safe when using the HSR	0.80	0.78	0.89	0.82	0.85	0.66	0.56	0.69
	(CS3) Expected services	0.59	0.70	0.86	0.71	0.46	0.83	0.67	0.65
Passenger Loyalty	(CL2) I will use HSR the next time I travel.	0.84	0.78	0.80	0.81	0.83	0.86	0.71	0.80
	(CL3) I will recommend the HSR to family and friends.	0.91	0.81	0.9	0.87	0.88	0.89	0.98	0.92
Corporate Image	(CI1) Departure punctuality	0.66	0.67	0.73	0.69	0.66	0.47	0.51	0.55
	(CI2) Service schedule meets customer requirements	0.91	0.66	0.7	0.75	0.79	0.76	0.63	0.73
	(CI3) The HSR corporate image	0.76	0.76	0.83	0.78	0.64	0.77	0.80	0.74
Operations Performance (Perceived market growth)	(OP1) Significantly increased growth in operations	N/A	0.86	0.96	0.91	N/A	0.82	0.66	0.74
	(OP2) Significantly increased profit rate		0.87	0.97	0.92		0.89	0.76	0.82
	(OP3) Significantly increased new market		0.65	0.50	0.58		0.56	0.56	0.56

In terms of passenger satisfaction, the factor loading for CS3 (Service Meets Expectations) consistently increased during 2007-2013, suggesting that deficiencies in high-speed rail service and fare increases have increased passenger expectations of high service quality. The values for passenger loyalty indicators CL2 (Intention to Ride Again) and CL3 (Intention to Recommend) were high in years 2007, 2010 and 2013. That is, both indicators indicated high explanatory ability for passenger loyalty. In terms of corporate image, the factor loading for CI1 (Punctuality) increased in 2013, suggesting that rapid commercial development has resulted in passengers placing a higher premium on time. Given recent service disruptions and delays, operating units must improve system maintenance to prevent delays and develop alternative fallback measures.

Since increased high-speed rail departures provide users with more varied travel options, indicator CI2 (Schedule Meets My Needs) fell significantly in 2010. In response, operating units should make appropriate adjustments to improve the passenger/departure ratio while avoiding unnecessary cost increases. Operating performance indicators OP1 (Increased Revenue) and OP2 (Increased Profitability) significantly increased in 2013 and exceeded 0.8 in 2010, suggesting that these two indicators highly explained operating performance.

Analysis results for KTX show that the values for the service quality dimension were relatively low, which may reflect an improving trend in service quality or the belief by passengers that the KTX is an essential service. In 2010, the value for SQ6 (Arrangements for Moving Lines) was comparatively low. Therefore, operators should attempt to maintain this advantage in the future and should determine what improvements and service requirements are needed to manage the expected increase in passenger volume.

From 2010 to 2013, the value for SQ12 (Quick Response to Inquiries) decreased significantly, suggesting that passenger complaints resulted in gradual improvements in KTX service quality. Since the values for SQ13 (Multiple Complaint Channels) were stable over the same time period, we speculate that this is a major factor in customer satisfaction. To improve service quality, KTX operators must further improve the convenience and availability of feedback channels and should encourage suggestions by passengers.

In terms of passenger satisfaction, the factor loading for indicator CS2 (Sense of Security) dropped significantly after 2010, indicating that passengers had a strong perception of safety. However, subsequent accidents caused a decrease in the safety perceived by passengers. Indicator CS3 (Service Meets Expectations) significantly increased after 2010. Thus, KTX should reexamine its customer service standards to ensure that they remain satisfactorily high to meet passenger expectations. The factor loadings were higher than 0.7 for passenger loyalty indicators CL2 (Intention to Ride Again) and CL3 (Intention to Recommend), which indicated these two factors highly explained the passenger loyalty construct for both systems.

The values for CI3 (Goodwill) gradually increased over time for KTX, which demonstrated the increasing explanatory power of CI3. Operational performance indicators OP1 (Increased Revenue) and OP2 (Increased Profitability) fell in 2013, suggesting the weak explanation about KTX revenues. Based on the timing of factor loading changes, we infer that the service factors most important to the public changed over time. These changes may have resulted from improvements to operating units and may also coincide with changes to social structures. However, further cross-analyses combining passenger satisfaction and passenger recognition are needed to compare the effects of different passenger requirements.

6.3 Passenger Satisfaction Index

For a clear understanding of the relationship between passenger behavior and operational performance, this study investigated passenger satisfaction with high-speed rail services. Table 6 shows the passenger satisfaction indices obtained by Eq. (13), which were used to quantify satisfaction levels for different passenger groups, categorized by gender, age and occupation in both countries.

A gender comparison shows that the satisfaction index for Taiwan passengers gradually increased over time in both men and women. Both genders had similar values in 2013. Korea showed no significant increase, and satisfaction among men

Table 6. Passenger Satisfaction Indicators for the Two Countries

Country		THSR						KTX					
Year		2007		2010		2013		2007		2010		2013	
Item		Sample percentage (%)	PSI	Sample percentage (%)	PSI	Sample percentage (%)	PSI	Sample percentage (%)	PSI	Sample percentage (%)	PSI	Sample percentage (%)	PSI
Gender	Male	47.6	59.80	51.7	69.13	45.1	77.99	34.3	55.13	53.5	51.39	49.8	46.59
	Female	52.4	68.01	48.3	67.80	54.9	78.55	65.7	52.85	46.5	50.00	50.2	52.13
Age	25 years and younger	17.2	65.10	27.0	68.34	44.2	78.52	20.5	53.21	30.0	57.00	63.1	50.06
	26 to 39 year	60.7	63.95	38.1	68.73	37.7	79.35	66.7	53.24	50.5	47.40	24.9	45.76
	40 years and older	22.1	50.50	35.0	68.42	18.2	75.39	12.8	57.06	19.5	51.09	12.0	55.32
Career	Student	24.9	55.80	15.4	64.00	38.2	78.62	48.1	52.92	22.5	55.22	68.7	49.78
	Commerce, service, manufacturing industries	51.7	57.63	42.5	69.87	30.9	76.65	15.9	55.21	35.0	49.00	11.4	47.75
	Other	23.5	70.89	42.1	68.70	31.0	80.68	36.0	55.38	37.0	49.76	20.0	48.92
Overall PSI		54.03		68.50		78.28		47.35		50.77		48.71	

dropped markedly in 2013. A comparison of passengers by age showed that THSR passengers aged 26-39 years had the highest service satisfaction while KTX passengers aged 40 and above had the highest service satisfaction. In passengers classified as working in "other professions" (including students), satisfaction was higher in Taiwan than in Korea. Overall, the passenger satisfaction index in Taiwan showed a gradual but statistically significant increase whereas the KTX passenger satisfaction levels showed little change.

The THSR passengers had significantly higher satisfaction levels for the following key service indicators: SQ1 (Comfortable Air Conditioning), SQ5 (Seat Comfort), SQ6-7 (Station Environment), SQ10 (Ease of Obtaining Schedule Information), SQ12-13 (Complaint Response), SQ14 (Ticket Machines), SQ16 (Personnel Attitude), CS2 (Sense of Safety), CS3 (Service Meets Expectations), CI1-2 (Departure Frequency), and CI3 (Goodwill). Table 7 compares the two high-speed rail systems in terms of these indicators.

High speed rail operators can use these indicators as a reference when attempting to increase KTX passenger satisfaction through improved service quality. To maintain high service standards, the THSR should consider the effects of indicators such as corporate image, passenger loyalty and operational performance when implementing the resource allocations and cost reductions needed to improve operational efficiency.

6.4 Strategies to Improve Operating Performance

This section describes how the relative importance of each indicator for improving operating performance at the current stage was measured. A two dimensional map of importance – passenger recognition/perception was applied while simultaneously considering the average value and initial questionnaire satisfaction score (minimum score, 5 points). To ensure a consistent analysis over multiple years, the 1-10 point scale of the 2007 evaluation (Chou and Kim, 2009; Chou *et al*., 2011) was normalized to a 1-7 point scale to facilitate observation of the allocation of corporate management resources over time.

Analyses of indicators that impacted operating performance in 2013 (see Fig. 6) showed that high-recognition and high-importance indicators include CI1 (Punctuality) and CI3 (Goodwill). Thus, high-speed rail company should be careful to maintain punctuality

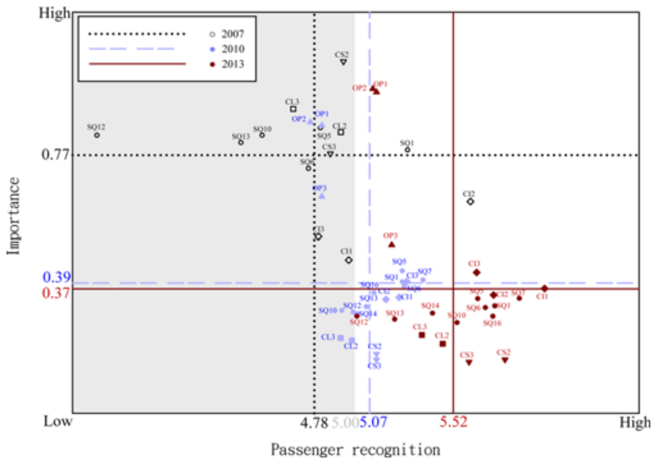

Fig. 6. Importance – Passenger Recognition Analysis for THSR Performance

Table 7. High-Speed Rail Service Comparison

Provider / Service indicator	THSR	KTX
Carriage seats	2+3 configuration with 4 handicapped seats	2+2 configuration with 2 handicapped seats
	Seats can rotate 180 degrees with adjustable seat backs	Seats do not rotate, limited recline angle
	Seats feature fold-down table tray	Independent folding tables
	Equipped with coat hanger	No coat hanger
Station	Approaching train indicated by lights located along the platform edge	No train approaching lights
	Grey soft seats	Metal seats
	Well-designed signage and indicators	Well-designed signage and indicators
Schedule information	Online inquiries	Online inquiries
	On-site schedule inquiries and displays	On-site schedule inquiries and displays
Complaint channels	Hard-copy customer feedback form	Hard-copy customer feedback form
	Direct feedback to onsite service personnel	Direct feedback to onsite service personnel
	Online feedback form	Online feedback form
	Customer service call center	Customer service call center
Ticket vending machines	Vending machines selling booking date (inclusive) for all trips in next 28 days. Ticketing stops 3 minutes before departure	Vending machines booking date (inclusive) for all trips in next 1 month. Ticketing stops 2 minutes before departure.
	No choice of seats	Choice of seats
	Pay by cash, credit cards, prepaid cards or debit card transfer	Pay by cash, credit cards, prepaid cards or debit card transfer
Number of departures	Average of 128-154 departures per day	Average of 200-232 departures per day
	Departures average one every half hour	Departures average 15 minutes (Gyeongbu Line)

Source: Compiled from the THSR, KTX official websites and related blogs by the authors.

and corporate goodwill to maintain high passenger recognition. Since indicators with high importance but low recognition included OP1 (Increased Revenue) and OP2 (Increased Profitability), operating units should survey passengers at stations to estimate development costs and the need for new stations, and this data can inform decisions to build new stations.

Low-recognition and low-importance indictors include SQ14 (Ease of Use of Ticket Vending Machines). Since these indicators had recognition scores of more than 5 ("somewhat agree" or "somewhat satisfied"), the THSRC should invest additional resources while maintaining current staffing levels. High-recognition but low-importance indicators include SQ16 (Personnel Attitude) and CI2 (Schedule Meets My Needs). The THSRC can improve these indicators by adjusting resources (*e.g.*, staffing levels and other inputs).

The analysis results for KTX showed service indicators with recognition scores below 5 (see Fig. 7), indicating passenger ambivalence. Therefore, resource allocation should be adjusted to achieve recognition levels of at least 5. In 2013, CI3 (Goodwill) was a high-recognition/high-importance indicator, suggesting that KTX must improve its public image. The OP3 (Continued Development of New Markets/Stations) was a low-recognition/high-importance indicator, suggesting that the company must perform a cost-benefit analysis before developing new stations, determine whether current station locations and schedules meet passenger demand, and adjust related strategies on this basis.

Over the three survey years (2007, 2010 and 2013), low-recognition/low-importance indicators included SQ5 (Seat Comfort) and SQ12 (Quick Response to Inquiries), which indicates that KTX should enhance passenger recognition improving these services. Since these indicators have a low importance in terms of operating performance, resource allocation should be performed by ranking the four quadrants in an effort to raise passenger recognition of the related services.

The high-recognition/low-importance indicators identified over the 3-year period of the study included SQ1 (Comfortable Air Conditioning) and SQ7 (Cleanliness). Although these indicators

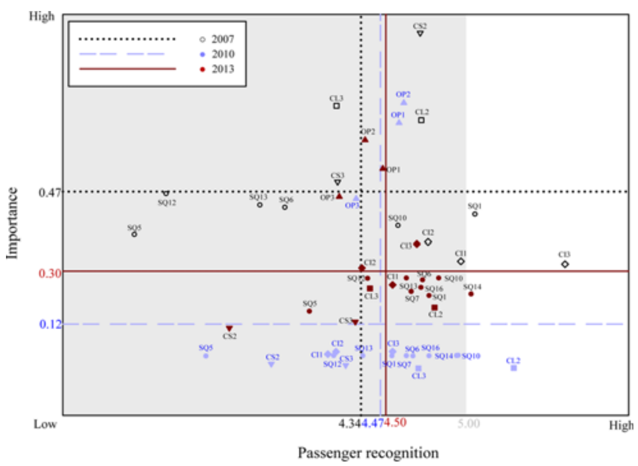

Fig. 7. Importance – Passenger Recognition Analysis for KTX Performance

fall in the low-importance quadrant, their recognition scores are below 5. Thus, human resources allocated to tasks related to these indicators should be minimized.

The most recent analysis results revealed high recognition scores for THSR services but low recognition scores for most KTX services. Therefore, the overall objective for the THSR is to evaluate the need to build new stations and add new departures to the schedule while maintaining or reducing overall human resource inputs. Most KTX service factors required additional management resource inputs, additional corporate image market research, investigation of low passenger recognition levels, improvements in related service quality, and continued tracking and assessment of passenger satisfaction.

7. Conclusions

After reviewing the relevant literature and actual high-speed rail operating conditions, this study developed an instrument for performing periodical surveys in investigations of the long-term performance of high-speed rail operations. Structural equation modeling was used for an empirical comparison of actual high-speed rail conditions in Taiwan and Korea. A transnational longitudinal comparison was also performed by combining the analysis results for path impact with the passenger recognition/satisfaction data collected by Chou and Kim (2009) (Chou and Kim, 2009), Chou *et al*. (2011) (Chou *et al*., 2011) and Chou and Yeh (2013) (Chou and Yeh, 2013).

Based on the updated analytical results, recommendations for improving service quality and operating performance were proposed. Overall passenger satisfaction results for the two countries show that the satisfaction level of Taiwan High Speed Rail (THSR) passengers rose from 54.03 in 2007 to 78.28 in 2013, indicating a significant rise in passenger satisfaction with THSR services. In contrast, passenger satisfaction for Korea Train eXpress (KTX) only slightly increased from 47.35 to 50.77 during the same period.

In terms of service quality, the most important THSR indicators were "Seat Comfort", "Station Cleanliness" and "Comfortable Air Conditioning". In the dimensions of passenger satisfaction, passenger loyalty, corporate image and operating performance dimensions, the most important indicators were "Sense of Safety", "Intention to Recommend", "Goodwill" and "Increased Profitability", respectively. For KTX, the important service quality indicators were "Ease of Obtaining Schedule Information", "Quick Response to Inquiries" and "Multiple Complaint Channels". The most important indicators for the passenger satisfaction, passenger loyalty, corporate image and operating performance dimensions were "Sense of Safety", "Intention to Recommend", "Goodwill", and "Increased Profitability", respectively. Operating units can apply these indicators in regular assessments of customer satisfaction and perceived service quality.

From 2007 to 2013, causal path analyses for both Taiwan and Korea indicate that operating performance is mainly affected by corporate image followed by passenger loyalty. In contrast, passenger satisfaction has the largest direct impact on passenger loyalty. These dimensions are all affected by service quality. Since all of these dimensions are affected by service quality, improving service quality is the key to improving operating performance. Therefore, optimally improving specific service items can improve overall operational efficiency with limited management resources. A cross-analysis of indicator importance and passenger recognition further showed that THSR recognition ratings scored 5 ("somewhat satisfied/agree") or above of a 1-7 scale in recent surveys, indicating a gradual improvement of the corresponding services and passenger perceptions. Recognition ratings for KTX are below 5 which indicated the need for an improved operating strategy.

Regarding the service quality dimension, the THSR should maintain its perception of excellent "Seat Comfort" and "Station Cleanliness" while improving "Quick Response to Inquiries", "Multiple Complaint Channels", "Ease of Use of Ticket Vending Machines", and "Ease of Obtaining Schedule Information". The company can also reduce costs by reducing or maintaining manpower allocated to "Comfortable Air Conditioning", "Station Location" and "Personnel Attitude". In contrast, the KTX should establish a highly positive corporate image by improving service quality in terms of "Station Location", "Ease of Obtaining Schedule Information", "Multiple Complaint Channels" and "Quick Response to Inquiries", followed by "Seat Comfort", "Comfortable Air Conditioning", "Cleanliness", "Ease of Use of Ticket Vending Machines" and "Personnel Attitude".

In summary, good service quality and corporate image are essential for good operating performance. Analysis of the service quality dimension showed that THSR passengers are mainly concerned with facility of infrastructure services whereas KTX passengers are mainly concerned with interaction with service personnel. The indicators for other dimensions showed that the THSR and KTX passengers had very similar concerns. For optimal resource allocation, however, THSR and KTX can achieve continuous improvements in customer satisfaction by improving customer complaint channels, scheduling information services, and being highly punctual.

The specific contribution of this study is the development of a systematic method of assessing the long-term performance of high-speed rail transport services, by which management units can adjust operating strategies to continuously improve service quality. The longitudinal analysis in this study compared passenger perceptions of high-speed rail service quality in Taiwan and Korea to determine how such services can best improve operating revenue. However, further studies are needed to address the following issues:

1. Since company personnel have the best insight into high-speed rail operations, further surveys of such personnel are needed to improve understanding of policies to improve operating performance.
2. Whereas this study was limited to high-speed rail services in Taiwan and Korea, future studies can consider samples from other countries to reassess similarities and differences in the adapted model, thus providing additional learning benchmarks for operating units.
3. Surveys in future studies can investigate the reasons for using high-speed rail and the frequency of high-speed rail travel to examine whether these factors correlate with passenger satisfaction, thus providing additional insight for detailed strategy recommendations.
4. Future research can modify the questionnaire for use in periodic repeated measurements by using panel data analysis to investigate the relation between passenger satisfaction, age, income and other socioeconomic characteristics for various countries over different time periods. Such an investigation will expose long-term passenger satisfaction trends and provide performance benchmarks for operating units.

References

Aksoy, L., Buoye, A., Aksoy, P., Larivière, B., and Keiningham, T. L. (2013). "A Cross-national investigation of the satisfaction and loyalty linkage for mobile telecommunications services across eight countries." *Journal of Interactive Marketing,* Vol. 27, No. 1, pp. 74-82, DOI: 10.1016/j.intmar.2012.09.003.

Anderson, E. W. and Fornell, C. (2000). "Foundations of the american customer satisfaction Index." *Total Quality Management,* Vol. 11, No. 7, pp. 869-882, DOI: 10.1080/09544120050135425.

Brons, M., Givoni, M., and Rietveld, P. (2009). "Access to railway stations and its potential in increasing rail use." *Transportation Research Part A: Policy and Practice,* Vol. 43, No. 2, pp. 136-149, DOI: 10.1016/j.tra.2008.08.002.

Burke, R. J., Graham, J., and Smith, F. (2005). "Effects of reengineering on the employee satisfaction-customer satisfaction relationship." *The TQM Magazine,* Vol. 17, No. 4, pp. 358-363.

Byrne, B. M. (2013). *Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming, Second Edition*: Taylor & Francis.

Calvo, I. F., Cantero, F., Oña, J. D., and Ortega, E. (2013). "Effect on demand for passenger rail of the extension of the Spanish high-speed network." *Ingegneria Ferroviaria*, pp. 1063-1080.

Cascetta, E., Papola, A., Pagliara, F., and Marzano, V. (2009). "Mobility and location impacts analysis of the HS Line Roma-Napoli." *Ingegneria Ferroviaria,* Vol. 64, Nos. 7-8, pp. 649-665.

Chathoth, P. K., Mak, B., Sim, J., Jauhari, V., and Manaktola, K. (2011). "Assessing dimensions of organizational trust across cultures: A comparative analysis of U.S. and Indian full service hotels." *International Journal of Hospitality Management,* Vol. 30, No. 2, pp. 233-242, DOI: 10.1016/j.ijhm.2010.09.004.

Chen, A., Lee, S., and Park, D. (2009). "Data modelling in transport." *Transportmetrica,* Vol. 6, No. 1, pp. 1-2, DOI: 10.1080/18128600902929575.

Chen, K.-Y. (2014). "Improving importance-performance analysis: The role of the zone of tolerance and competitor performance. The case of Taiwan's hot spring hotels." *Tourism Management,* Vol. 40, pp. 260-272, DOI: 10.1016/j.tourman.2013.06.009.

Cheng, Y.-H. (2010). "High-speed rail in Taiwan: New experience and issues for future development." *Transport Policy,* Vol. 17, No. 2, pp. 51-63, DOI: 10.1016/j.tranpol.2009.10.009.

Chi, C. S. F. and Javernick-Will, A. N. (2011). "Institutional effects on project arrangement: High-speed rail projects in China and Taiwan." *Construction Management and Economics,* Vol. 29, No. 6, pp. 595-

611.

Chou, J.-S. and Kim, C. (2009). "A structural equation analysis of the QSL relationship with passenger riding experience on high speed rail: An empirical study of Taiwan and Korea." *Expert Systems with Applications,* Vol. 36, No. 3, Part 2, pp. 6945-6955, DOI: 10.1016/j.eswa.2008.08.056.

Chou, J.-S., Kim, C., Kuo, Y.-C., and Ou, N.-C. (2011). Deploying effective service strategy in the operations stage of high-speed rail. *Transportation Research Part E: Logistics and Transportation Review,* Vol. 47, No. 4, pp. 507-519, DOI: 10.1016/j.tre.2010.12.004.

Chou, J.-S. and Yeh, C.-P. (2013). "Influential constructs, mediating effects, and moderating effects on operations performance of high speed rail from passenger perspective." *Transport Policy*, Vol. 30, 207-219, DOI: 10.1016/j.tranpol.2013.09.014.

Chou, P.-F., Lu, C.-S., and Chang, Y.-H. (2014). "Effects of service quality and customer satisfaction on customer loyalty in high-speed rail services in Taiwan." *Transportmetrica A: Transport Science,* Vol. 10, No. 10, pp. 917-945.

Costa-Font, M. and Gil, J. M. (2009). "Structural equation modelling of consumer acceptance of Genetically Modified (GM) food in the Mediterranean Europe: A cross country study." *Food Quality and Preference,* Vol. 20, No. 6, pp. 399-409, DOI: 10.1016/j.foodqual.2009.02.011.

de Oña, R. and de Oña, J. (2015). "Analysis of transit quality of service through segmentation and classification tree techniques." *Transportmetrica A: Transport Science*, Vol. 11, No. 5, pp. 365-387, DOI: 10.1080/23249935.2014.1003111.

Eboli, L. and Mazzulla, G. (2012). "Structural equation modelling for analysing passengers' perceptions about railway services." *Procedia - Social and Behavioral Sciences,* Vol. 54, pp. 96-106, DOI: 10.1016/j.sbspro.2012.09.729.

Fornell, C. and Larcker, D. F. (1981). "Evaluating structural equation models with unobservable variables and measurement error." *Journal of Markting Research,* Vol. 18, pp. 39-50.

Geng, X. and Chu, X. (2012). "A new importance–performance analysis approach for customer satisfaction evaluation supporting PSS design." *Expert Systems with Applications*, Vol. 39, No. 1, pp. 1492-1502, DOI: 10.1016/j.eswa.2011.08.038.

Givoni, M. and Rietveld, P. (2007). "The access journey to the railway station and its role in passengers' satisfaction with rail travel." *Transport Policy,* Vol. 14, No. 5, pp. 357-365, DOI: 10.1016/j.tranpol.2007.04.004.

Hair, J., Black, W., Babin, B., and Anderson, R. (2009). *Multivariate Data Analysis (7th Edition)*: Prentice Hall.

Hansen, J. D., Deitz, G. D., Tokman, M., Marino, L. D., and Weaver, K. M. (2011). "Cross-national invariance of the entrepreneurial orientation scale." *Journal of Business Venturing,* Vol. 26, No. 1, pp. 61-78, DOI: 10.1016/j.jbusvent.2009.05.003.

Hsu, S.-H., Chen, W.-H., and Hsueh, J.-T. (2006). "Application of customer satisfaction study to derive customer knowledge." *Total Quality Management*, Vol. 17, No. 4, pp. 439-454.

Jou, R.-C., Lam, S.-H., Hensher, D. A., Chen, C.-C., and Kuo, C.-W. (2008). "The effect of service quality and price on international airline competition." *Transportation Research Part E: Logistics and Transportation Review,* Vol. 44, No. 4, pp. 580-592, DOI: 10.1016/j.tre.2007.05.004.

Karatepe, O. M. (2006). "Customer complaints and organizational responses: The effects of complainants' perceptions of justice on satisfaction and loyalty." *International Journal of Hospitality Management,* Vol. 25, No. 1, pp. 69-90, DOI: 10.1016/j.ijhm.2004.12.008.

Kline, R. B. (2011). *Principles and Practice of Structural Equation Modeling* (Vol. 3): Guilford Press.

Korail (2004). *The survey of KTX (Korea Train eXpress) passengers' motion sickness*, Korea Railroad Corporation, Seoul, Korea.

Korail (2015). Korea Railroad Corporation.

Kuo, C.-W. and Jou, R.-C. (2014). "Asymmetric response model for evaluating airline service quality: An empirical study in cross-strait direct flights." *Transportation Research Part A: Policy and Practice,* Vol. 62, pp. 63-70, DOI: 10.1016/j.tra.2014.02.004.

Lai, W.-T. and Chen, C.-F. (2011). "Behavioral intentions of public transit passengers—The roles of service quality, perceived value, satisfaction and involvement." *Transport Policy,* Vol. 18, No. 2, pp. 318-325, DOI: 10.1016/j.tranpol.2010.09.003.

Meuleman, B., Davidov, E., and Billiet, J. (2009). "Changing attitudes toward immigration in Europe, 2002–2007: A dynamic group conflict theory approach." *Social Science Research*, Vol. 38, No. 2, pp. 352-365, DOI: 10.1016/j.ssresearch.2008.09.006.

Mueller, R. D., Palmer, A., Mack, R., and McMullan, R. (2003). "Service in the restaurant industry: An American and Irish comparison of service failures and recovery strategies." *International Journal of Hospitality Management,* Vol. 22, No. 4, pp. 395-418, DOI: 10.1016/S0278-4319(03)00072-0.

Sadikoglu, E. and Zehir, C. (2010). "Investigating the effects of innovation and employee performance on the relationship between total quality management practices and firm performance: An empirical study of Turkish firms." *International Journal of Production Economics,* Vol. 127, No. 1, pp. 13-26, DOI: 10.1016/j.ijpe.2010.02.013.

Szymanski, D. M. and Henard, D. H. (2001). "Customer satisfaction: a meta-analysis of the empirical evidence." *Journal of the Academy of Marketing Science,* Vol. 29, No. 1, pp. 16-35, DOI: 10.1177/009207030102900102.

Yee, R. W. Y., Yeung, A. C. L., and Cheng, T. C. E. (2008). "The impact of employee satisfaction on quality and profitability in high-contact service industries." *Journal of Operations Management*, Vol. 26, No. 5, pp. 651-668, DOI: 10.1016/j.jom.2008.01.001.

Yee, R. W. Y., Yeung, A. C. L., and Edwin Cheng, T. C. (2010). "An empirical study of employee loyalty, service quality and firm performance in the service industry." *International Journal of Production Economics,* Vol. 124, No. 1, pp. 109-120, DOI: 10.1016/j.ijpe.2009.10.015.

Yeh, C.-H. and Kuo, Y.-L. (2003). "Evaluating passenger services of Asia-Pacific international airports." *Transportation Research Part E: Logistics and Transportation Review*, Vol. 39, No. 1, pp. 35-48, DOI: 10.1016/S1366-5545(02)00017-0.

Yuksel, A., Kilinc, U., and Yuksel, F. (2006). "Cross-national analysis of hotel customers' attitudes toward complaining and their complaining behaviours." *Tourism Management*, Vol. 27, No. 1, pp. 11-24, DOI: 10.1016/j.tourman.2004.07.007.