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High speed rail passengers' mobile ticketing adoption

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ABSTRACT

This study examines high speed rail (HSR) passengers' acceptance of mobile ticketing services, as indicated by their mobile access for ticketing information inquiries and use of quick response codes (QR codes) for payment and gate entrance. This study contributes to developing a theoretical framework that brings together mental accounting theory and the technology acceptance model (TAM) to examine consumers' decision to adopt mobile ticketing. Structural equation modeling was adopted to examine the research hypotheses based on the proposed theoretical framework. The analytical results provide empirical evidence that a combination of the mental accounting theory and TAM is appropriate for explaining passengers' mobile ticketing service adoption. The findings demonstrate that personal innovativeness has a positive effect on the both mobile access adoption and QR code adoption. Although perceived risk, perceived usefulness, and perceived ease of use all influence QR code adoption, mobile access adoption is not directly affected by perceived risk or perceived ease of use. However, the perceived usefulness associated with such a system has a positive and direct influence on mobile access adoption. Moreover, the findings with respect to the interaction between potential benefit and potential loss of adopting a QR code service show that perceived risk not only directly affects passengers' mobile ticketing adoption but also offsets the influence of the construct of "perceived usefulness" on passengers' adoption intention. The conclusions of this study have managerial implications for HSR system operators and may be generalized to the application of mobile ticketing in other transportation industries.

1. Introduction

The ever-increasing popularity of intelligent mobile phones has induced greater use of mobile access and, thus, changed in the usage patterns of traditional online channels. Mobile access of the Internet can stimulate the development of mobile commerce (m-commerce), which is believed will greatly affect business and society in the coming years (Büyüközkan, 2009). The benefits of adopting an online distribution channel have been acknowledged in related studies (Lu et al., 2011; Xia and Zhang, 2010). Thus, the potential applicability of a mobile channel is increasingly being emphasized from the perspective of various industries. However, the user's acceptance toward this new mobile technology warrants further examination to derive a more appropriate and user-friendly mobile technology for potential users.

Because personal mobile devices have been progressively adopted in marketing, distribution, and ticketing in recent years, the quick response code (QR code) has become one of the popular tools to utilize. The QR code, a kind of two-dimensional barcode, was introduced to the market in 1994 by the Japanese corporation Denso Wave (Kieseberg et al., 2010; Gu and Zhang, 2011). Regarding ticketing, both technologies—mobile access to the Internet (referred to hereafter as "mobile access") and the QR code—are employed. In terms of information inquiries, ticket booking, and payment stages, mobile access

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enables consumers to access the required information and services whenever and from wherever they want. A QR code can be either printed on physical tickets or utilized as intangible tickets, e.g., through an electronic mobile ticket issued by a mobile phone to a passenger. Although these uses have yet to become popular in most transportation systems, the potential applicability of a mobile technology-oriented distribution channel (for ease of reference, referred to hereafter simply as a "mobile channel") can be anticipated in the future. Thus, this study takes into account the anticipated applications of mobile access and QR code mobile technology and investigates users' decision to adopt these applications within the four stages of the ticket purchasing process for a high speed rail (HSR) system.

Most HSR passengers use the railway station ticket counters to buy tickets and inquire about train information from the timetable brochures. However, most HSR stations are not easily accessible. Therefore, the mobile service of an HSR system operator can be considered an essential channel for HSR passengers to access travel information for searching, trip planning, making reservations, and ticket purchasing. This study uses the example of the Taiwanese High Speed Rail (THSR). At the beginning of its operations in early 2007, the THSR provided passengers with a single channel (THSR stations) from which to purchase tickets. To overcome the disadvantages resulting from the limitation of utilizing only a single channel, the THSR then developed other distribution channels, such as a 24-h online channel and ticketing through convenience stores. The implementation of a multi-channel strategy and utilization of a mobile channel within the transportation industry can result in greater convenience for users.

Previous relevant studies have rarely focused on HSR passengers' acceptance of mobile technologies for ticket purchasing. Studies on mobile technology applications have increased in significance during the past few years, and most of them have focused on user acceptance. Because mobile devices have become much more popular and affordable, it is believed that user acceptance should be extended to obtain other value-added services and potential risks. From a theoretical perspective, the technology acceptance model (TAM) is considered a common and robust theoretical foundation on which to base a study of multi-channel preferences, but it only considers the benefits of using a given technology; TAM does not account for the loss or resistance factor and does not allow a gain–loss analysis. Thus, the present study examines resistance factors, such as perceived risk, in HSR passengers' adoption of mobile technologies in ticket purchasing. The mental accounting framework was adopted to examine consumer behavior in the case of behavior that depends on the type of exposure units with either positive or negative experiences.

Compared with the relevant studies on mobile commerce, this study contributes to the literature by combining mental accounting theory and a revised version of the TAM to examine more appropriately HSR passengers' mobile ticketing service adoption. The research framework was based on mental accounting theory, and the well-developed measurement scale derived from the TAM is still applicable in this study. In the present study, HSR passengers' mobile ticketing service adoption was determined based on two main components: perceived potential benefit and perceived potential sacrifice. The perceived risk construct is considered the potential sacrifice perceived by the user. The perceived ease of use and perceived usefulness constructs are deemed to be the potential benefit to HSR users. The relationship between the potential benefit and the potential sacrifice is also examined. The findings with respect to the interaction between the potential benefit and the potential sacrifice of adopting the mobile ticketing service indicate the influence of positive and resistance factors and their interaction, which affect mobile ticketing technology adoption. A clear understanding of these interactions between positive and resistance factors may help HSR operators develop appropriate deployment strategies for mobile ticketing services.

To further examine the central questions of the present study, the following section is organized to investigate HSR passengers' acceptance of mobile ticketing. The first section describes the objective of this study and issues related to using mobile technologies. The second section discusses some features of utilizing mobile technologies and the theoretical grounds for this study. The third section discusses the research model and, using mental accounting theory and the TAM, formulates hypotheses regarding HSR passengers' adoption of mobile ticketing services, namely, mobile access and QR codes. The fourth section discusses the data collection and variable measurements. The empirical results, including scale validation, a path coefficient analysis, and a comparison of the two models, are presented in the fifth section. Finally, conclusions and some managerial implications are provided.

2. Theoretical background

2.1. Utilization of mobile technologies

The first decade of the 21st century has been considered the decade of mobile computing (Mahatanankoon et al., 2005). In recent years, as information technology and living conditions have improved, personal mobile devices have become progressively more popular and affordable worldwide. Accordingly, mobile commerce (m-commerce) is developing and progressing (Ngai and Gunasekaran, 2007). Ngai and Gunasekaran (2007) indicated that m-commerce may be considered a subset of electronic commerce (e-commerce). Like e-commerce, users may be concerned about similar weaknesses in the mobile environment, such as business concerns, privacy protection, security, and perceived risks (Wu and Wang, 2005).

Currently, m-commerce and its extensions, such as mobile ticketing and mobile payments, have been widely implemented in different fields, including the banking, insurance, and transportation industries (Laukkanen and Lauronen, 2005; Lee et al., 2007; Mallat et al., 2009). One of the successful adoptions of m-commerce in the transportation industry is found in Helsinki, Finland, where it is utilized by the Helsinki Public Transportation Authority (Mallat et al., 2009). The

example of Finn Air shows that m-commerce can be applicable to the airline passenger check-in process because of low maintenance costs and outstanding availability (Liljander et al., 2006). M-commerce can be regarded as an innovative commercial tool (Mallat et al., 2009; Wu and Wang, 2005). Table 1 briefly presents the factors that affect the acceptance of m-commerce as found in the relevant literature. However, previous relevant studies rarely have examined the application of mobile technology to the complete ticket purchasing process, including information inquiry, ticket booking, payment stages, and ticket check-in.

2.2. Mental accounting theory

Mental accounting theory was proposed in 1985 by Thaler, who based its development on the prospect theory value function. The mental accounting framework of Thaler (1985) primarily examines consumer behavior in the case of two components: positive and negative outcomes. Mental accounting is defined as "the set of cognitive operations used by individuals and households to organize, evaluate, and keep track of financial activities" (Thaler, 1999). The mental accounting theory allows for an explanation of consumer choices under conditions of risk and uncertainty (Gupta and Kim, 2010; Kim and Gupta, 2009; Milkman and Beshears, 2009). More specifically, mental accounting theory provides researchers with a theoretical basis to explain how consumers maximize the utility of a decision through a process of identifying, categorizing, and assessing multiple events relative to any given specific decision (Chu and Liao, 2010).

Consumers decide whether to carry out the potential adoption based on an evaluation of perceived value, which is defined as the net benefits (perceived benefits relative to perceived sacrifices) of an adoption (Gupta and Kim, 2010). Effectively, individuals are loss averse with regard to purchasing decisions (Barberis and Huang, 2001). In other words, consumers will not carry out a transaction involving a higher degree of perceived sacrifice (risk) over perceived benefits. Furthermore, previous studies on mental accounting indicated that, instead of thinking over all decisions as a single optimization problem, consumers tend to integrate mentally the issues of their financial resources and expenditures and, thus, make their decisions based on the context of each narrowly defined "account" (Milkman and Beshears, 2009). HSR passengers can decide to use the mobile ticketing technology through a mental process that considers the trade-off between potential benefit and potential risk. Because HSR mobile ticketing technology usage behavior may be reasonably divided into several purchasing stages, and these stages may well be affected by various decision factors, mental accounting theory is believed to be an appropriate theoretical basis for the present study (Gupta and Kim, 2010; Schoenbachler and Gorden, 2002).

2.3. Technology acceptance model (TAM)

The technology acceptance model (TAM), which is based on the theory of reasoned action (TRA) (Ajzen and Fishbein, 1980), was developed by Davis (1989). The TAM has been widely implemented to investigate user acceptance and utilization of information technology or information systems (Ahn et al., 2004; Shih, 2004). Two major beliefs—perceived usefulness and perceived ease of use—are proposed as key factors of the TAM (Davis et al., 1989). Perceived usefulness was defined as "the degree to which a potential user believes that using a specific system would increase his or her job performance." Perceived ease of use was defined as "the degree to which a potential user believes that using a specific system would be free of effort" (Davis et al., 1989; Shih, 2004). TAM assumes that the perception of an innovative technology (i.e., perceived usefulness and perceived ease of use) affecting the development of attitudes toward any given technology eventually leads to an understanding of a given technological system's usage behavior (Ahn et al., 2004) (Fig. 1).

The TAM has been demonstrated as a robust theoretical basis for exploring users' adoption of innovative technologies in various contexts, such as online shopping, Internet banking, and mobile commerce (Ha and Stoel, 2009). In this study, the multiple channels developed and adopted by the THSR simultaneously consist of traditional offline channels and innovative channels; thus, the TAM is considered a suitable framework for analyzing consumers' behavioral intentions and actual utilization of channel portfolios. However, resistance factors, such as perceived risk essential to a user's mobile commence adoption, were not adopted in previous studies relevant to the TAM.

Keeney (1994) indicated that values and not alternatives should be the primary focus of decision making. Keeney (1999) employed a customer's value notion to examine individual adoption toward Internet commerce. Using an iterative value-focused approach, he proposed a set of related variables that together help managers understand what might influence a consumer to shop online. Following the study of Keeney (1999) and Chang et al. (2004) examined the two hypothesized measurement models and the proposed second-order model using a sample of 331 responses. The results confirm the factor structures of the two models and suggest a more parsimonious instrument for each; a 5-factor, 15-item scale for means objectives and a 4-factor, 8-item scale for fundamental objectives. Torkzadeh and Dhillon (2002) applied two sets of variables to measure means objectives and fundamental objectives for Internet commerce. They used a sample of 620 people in a two-phase study and proposed five first-order factors—product choice, online payment, vendor trust, shopping travel, shipping errors—measured by 21 items for means objectives.

Previous studies using the TAM have rarely examined the interactive effect between perceived sacrifice and perceived benefits (Keeney, 1994, 1999; Chang et al., 2004; Torkzadeh and Dhillon, 2002; Featherman and Pavlou, 2003). Our study combines mental accounting theory and the TAM and attempts to further examine the interrelationship between perceived sacrifice and perceived benefits and the relative importance of their influence on HSR Passengers' mobile ticketing adoption decisions.

Table 1
Factors affecting m-commerce acceptance proposed by relevant studies.

Author	Research objective	Factors affecting preferences
Wu and Wang (2005)	Identify factors driving m-commerce	• Perceived risk • Cost • Compatibility • Perceived usefulness • Perceived ease of use
Kim et al. (2007)	Understanding of consumers' adoption behavior and provision of service developers with practical suggestions	• Perceived value • Usefulness • Enjoyment factor • Degree of technicality • Perception of Fees
Mallat et al. (2009)	Investigate the effect of use context on mobile services acceptance	• Ease of use • Usefulness • Compatibility • Mobility • Use context
Kuo and Yen (2009)	Identify factors affecting consumers' behavioral intention to adopt 3G mobile value-added services and analyze the relationships among these factors	• Personal innovativeness • Perceived usefulness • Perceived ease of use • Perceived cost • Attitude

3. Research model and hypotheses

3.1. Purchasing tickets through mobile channels

The originality of this study results from examining HSR passengers' mobile ticketing adoption in the four stages of the ticket purchasing process—information inquiry, ticket booking, payment, and ticket check-in—which have rarely been examined in previous studies. In the inquiry stage, passengers were allowed to use their own cell phones to visit the THSR website and search for required information, such as timetables, fares, and special promotions. Next, passengers were able to directly book tickets through mobile access. Payment for the tickets was charged to the passengers through their mobile phone service provider's billing system (Mallat et al., 2008). The THSR tickets were then sent to users' cell phones in the form of an intangible ticket that utilized a QR code for gate entrance. However, because Taiwanese passengers are more familiar with mobile access than QR codes, pictures were provided to help respondents better understand the use of the QR code within their purchased intangible THSR tickets (Fig. 2). Evaluating the acceptance of these two technologies in a single model is inappropriate because of their distinct features and user concerns. Thus, mobile access and QR codes are separately examined by considering the different stages using behavior related to the ticket purchasing process.

3.2. Conceptual research model

Compared with previous studies on mobile commerce, reason-based choice models are also able to address adoption decisions. However, respondents were asked to report the reasons for their decision. Unfortunately, the actual reasons that guide decisions may or may not correspond to those reported by the subjects. Respondents are sometimes unaware of the precise factors that affect their choices and generate spurious explanations when asked to account for their decisions (Shafir et al., 1993). Furthermore, numerous studies on customer choice and decision making in the fields of economics and marketing (Chang and Wildt, 1994; Chen and Dubinsky, 2003; Dodds et al., 1991; Zeithaml, 1988) have acknowledged value as an important determinant of mobile commerce. Therefore, a value-based model, namely, the mental accounting model, is adopted. In addition, the advantages of the TAM are incorporated into our research model. Because the TAM has been widely employed in research on acceptance of innovative technologies, the relevant measurement scale and items are comparatively well developed. However, the TAM does not consider potential sacrifices, such as financial losses or violations of privacy. Risk of financial losses in this study is related to the possible losses arising from mobile payment errors and financial transactions fraud.

Thus, our research framework attempts to combine the TAM and mental accounting theory to examine HSR passengers' intention to adopt mobile ticketing technology (Fig. 3). Thaler (1999) indicated that the perceived value of the adoption decision is represented by a value function. In our study, the value function is influenced by positive (perceived ease of use and perceived usefulness constructs) and negative outcomes (perceived risk construct). As previous studies have indicated, risk issues are important barriers to the adoption of mobile ticket technology (Miyazaki and Fernandez, 2001; Gupta and Kim, 2010). Hence, the construct of perceived risk is employed to observe passengers' concerns for the potential loss or inconvenience of using mobile ticketing technology. In terms of positive experiences with mental accounting theory, mobile access and QR codes are comparatively innovative technologies for many Taiwanese passengers. Thus, this research adopts the TAM

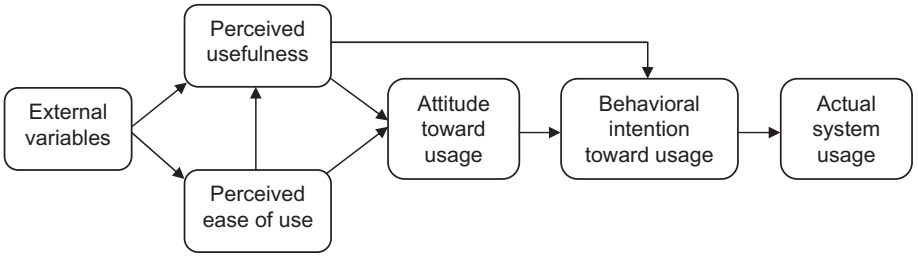

Fig. 1. Technology acceptance model. *Source*: Davis et al. (1989).

as a part of its theoretical basis. Perceived usefulness and perceived ease of use, which correspond to dimensions in previous studies, are used to assess the potential benefits of using mobile channels. Thus, HSR passengers can perceive value by assessing the potential loss and gain from adopting mobile ticket technology.

Moreover, personal innovativeness has been confirmed as an important factor that affects the adoption of new technologies (Kuo and Yen, 2009). The relative immaturity of mobile services adoption in the transport industry leads to the importance of examining "personal innovativeness" as an influencing variable in new circumstances, which is added to the research model as well. The contextual factors such as social influence, economic environment, technological environment were not considered in our research model is because this study mainly aims to examine the influence of perceived value perspective on HSR passenger's mobile ticketing adoption decision. Furthermore, the QR code use for Taiwan HSR passengers was still in the test-trial stage. The application context of the QR code is not compatible with ordinary users of new information equipment or services, such as mobile phones or the Internet. Most users are not familiar with this brand new service; therefore, the contextual factors do not seem to be a significant construct affecting QR code adoption for HSR ticketing services in this stage. Contextual factors can be further examined in the future study.

3.3. Research hypotheses

Personal innovativeness represents an individual's willingness to accept new things or new concepts and even to try new products or services (Rogers, 1995; Kuo and Yen, 2009). Aside from the benefits resulting from using a new product, consumers are also influenced by their own beliefs in innovativeness. Note that personal innovativeness mediates users' decisions to adopt information technology (Agarwal and Prasad, 1998; Kuo and Yen, 2009). Researchers found that higher personal innovativeness causes more positive adoption behavior (Kuo and Yen, 2009). Previous research studies have demonstrated that personal innovativeness is a useful predictor of adoption of new technologies, such as online shopping and mobile services (Limayern et al., 2000; Goldsmith, 2000; Yang, 2005; Kuo and Yen, 2009). Notably, QR codes and mobile access are considered new applications for HSR passengers. Therefore, hypotheses H1a and H2a are derived.

Agarwal and Prasad (1998) considered personal innovativeness to be a symbol of the risk-taking propensity that exists in certain individuals and not in others. Individuals with high personal innovativeness are able to cope with high levels of uncertainty and develop more positive intensions toward acceptance (Rogers, 1995). In a context of uncertainty in using a brand new service, mobile ticketing technology during HSR passenger travel, personal innovativeness is considered an essential construct that affects users' adoption under uncertainty. Moreover, Aldás-Manzano et al. (2009) indicated that there is an influence of personal innovativeness on risk taking and usage intentions. Hence, hypotheses H1b and H2b are derived.

Moreover, Citrin et al. (2000) revealed that personal innovativeness predicts consumer adoption of Internet shopping. Given the relative immaturity of mobile services adoption in the transport industry, it is appropriate to examine personal

Fig. 2. Illustration of QR code usage. *Source*: http://www.airlinecio.com/airline-cio-blog/tag/barcode; http://zh.wikipedia.org/wiki/QR%E7%A2%BC; http://www.mad4mobilephones.com/bar-code-train-tickets-on-your-phone/731/.

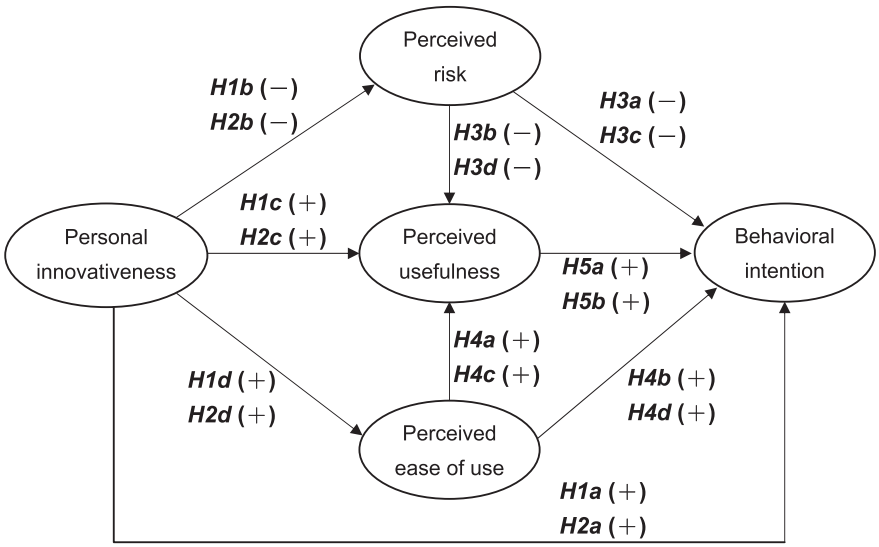

Fig. 3. Research model for acceptance of mobile Internet and QR code.

innovativeness as an influencing variable under new circumstances. Previous studies have also demonstrated that personal innovativeness can have a strong effect on perceived usefulness and perceived ease of use, which in turn influences user intention to adopt m-commerce (Bhatti, 2007). Therefore, the personal innovativeness–perceived usefulness (H1c, H2c) relationship and the personal innovativeness–perceived ease of use (H1d, H2d) relationship are examined in this study.

H1a. Personal innovativeness positively affects mobile access adoption.

H1b. Personal innovativeness negatively affects the perceived risk of using mobile access.

H1c. Personal innovativeness positively affects the perceived usefulness of mobile access.

H1d. Personal innovativeness positively affects the perceived ease of using mobile access.

H2a. Personal innovativeness positively affects QR code adoption.

H2b. Personal innovativeness negatively affects the perceived risk of using QR codes.

H2c. Personal innovativeness positively affects the perceived usefulness of QR codes.

H2d. Personal innovativeness positively affects perceived ease of using QR codes.

3.3.1. Perceived risk

Perceived risk is a critical barrier for consumers in an online environment, and it can be thought of as consumers' belief about the potential negative outcomes resulting from the use of mobile ticketing technology (Kim et al., 2008). Risk perception is also important to consumers who are considering whether to adopt mobile technology. In some studies on the acceptance of new technology, researchers may use the attributes of trust or security to represent consumers' concerns about the protection of personal information or privacy; however, perceived trust, perceived security, and perceived risk are basically derived from the same concept covering privacy regarding financial threats (Gao et al., 2010). With respect to behavioral intentions, Kim et al. (2008) have provided evidence that perceived risk is negatively associated with behavioral intention (Kim et al., 2008; Luo et al., 2010; Miyazaki and Fernandez, 2001). Thus, H3a and H3c are hypothesized.

Perceived risk is considered to lower consumer evaluations of many different types of goods and services (Dowling and Staelin, 1994; Mitchell and Greatorex, 1993). Several relevant studies have also demonstrated that perceived risk negatively influences perceived usefulness toward online shopping (Jarvenpaa et al., 2000; Liu and Wei, 2003; Van der Heijden et al.,

2003; Featherman and Pavlou, 2003). Similar to e-services, mobile services requiring the transmission and storage of sensitive information are apt to be deemed less useful by passengers who consider the possible exposure to security breaches, potential privacy losses, and the misuse of personally identifiable information (Featherman et al., 2010). Therefore, our study aims to examine whether the perceived risk is negatively related to perceived usefulness of a QR code application when taking the HSR train. Based on previous research, we propose our hypotheses related to perceived risk (H3b and H3d).

H3a. Perceived risk negatively affects mobile access adoption.

H3b. Perceived risk negatively affects the perceived usefulness of mobile access.

H3c. Perceived risk negatively affects QR code adoption.

H3d. Perceived risk negatively affects the perceived usefulness of QR codes.

3.3.2. Perceived usefulness, perceived ease of use, and behavioral intention

The positive effects of perceived ease of use on perceived usefulness and behavioral intention have been confirmed in many studies related to the TAM (Wu and Wang, 2005; Khalifa and Shen, 2008; Ha and Stoel, 2009; Kuo and Yen, 2009; Mallat et al., 2009; Schierz et al., 2010). Previous studies have indicated that perceived ease of use is able to reinforce users' perceived usefulness (Liao et al., 2007; Kuo and Yen, 2009). Moreover, a higher perceived ease of use generally results in higher perceived usefulness and eventually has a positive influence on behavioral intention (Wu and Wang, 2005; Liao et al., 2007; Kuo and Yen, 2009). However, some studies adopting the TAM as an analysis tool might connect perceived usefulness and behavioral intention through the construct of attitudes. Therefore, hypotheses H4a, H4b, H4c, and H4d are derived. Other researchers have argued that attitude factors can be removed given the insignificant effect between attitudes and behavioral intention (Wu et al., 2011). Thus, this study ignores the attitude factor. Furthermore, Mallat et al. (2009) proposed that perceived ease of use and perceived usefulness might have positive and direct effects on behavioral intention. Kim et al. (2010) revealed that perceived usefulness has a direct and positive influence on behavioral intention. Hypotheses H5a and H5b are argued accordingly.

H4a. Perceived ease of use positively affects the perceived usefulness of mobile access.

H4b. Perceived ease of use positively affects mobile access adoption.

H4c. Perceived ease of use positively affects the perceived usefulness of QR codes.

H4d. Perceived ease of use positively affects QR code adoption.

H5a. Perceived usefulness positively affects mobile access adoption.

H5b. Perceived usefulness positively affects QR code adoption.

4. Research methodology

4.1. Data collection

The sample for this study consisted of passengers who have had experience purchasing THSR tickets and who use mobile phones. In random sampling, each element of the population has an equal chance of being chosen at each draw. However, conducting random sampling in practice is difficult. Therefore, this study used the systematic sampling method to replace the random sampling method. Systematic sampling is a statistical method involving the selection of elements from an ordered sampling frame. The most common form of systematic sampling is an equal-probability method in which every kth element in the frame is selected. The sampling interval, k, is calculated as follows:

$$k = \frac{N}{n}$$

where n is the sample size and N is the population size. Using this procedure, each element in the population has a known and equal probability of selection, making systematic sampling functionally similar to simple random sampling (Bowerman

et al., 2004). Our questionnaires were distributed to every fifth passenger at the main entrance of the Tainan and Kaohsiung HSR stations during the study period, which was from March 30 to April 15, 2011.

4.2. Variable measurements

Variable measurements primarily based on the hypothesized model (Fig. 3) were developed through a detailed review of the relevant literature on mobile commerce, perceived risk, the TAM, mental accounting theory, and personal innovativeness; in addition, two measurement items were developed to measure the two different mobile technology applications, namely, mobile access and QR codes. The measurement items under the constructs of personal innovativeness, perceived risk, perceived usefulness, and perceived ease of use were mainly taken to from prior relevant studies. Specific characteristics the mobile technology service as it relates to the four stages of the ticket purchasing process were also considered when developing the measurement items in this study. Based on the notion of transaction cost in the mental accounting model, the measurement items under the main constructs were derived from the comparison value perceived by respondents by comparing the QR code service and the physical ticket service in the present study.

4.2.1. Personal innovativeness

This survey used the construct of personal innovativeness to reflect passengers' acceptance of new services. The measurement items were adapted from previous relevant studies (Kuo and Yen, 2009; Kim et al., 2010; Hung et al., 2003; Yang, 2005). The proposition regarding why personal innovativeness is linearly related to measurement items is primarily based on prior relevant studies (Kuo and Yen, 2009; Kim et al., 2010; Hung et al., 2003; Yang, 2005). The measurement items under the construct of personal innovativeness are as follows: I am always interested in most up-to-date products, I am curious about various things, and I usually purchase the new products.

4.2.2. Perceived risk

In terms of perceived risk, this study evaluated the protection of personal information and the prevention of financial loss. Users may also be concerned about the reliability of innovative ticketing systems (Mallat et al., 2008). Therefore, this study used these items to evaluate passengers' beliefs regarding the reliability of mobile channels. The measurement items under the construct of perceived risk were taken from Kim et al. (2010) and Mallat et al. (2008).

Perceived risk is not a reflective construct; it is a formative factor. Thus, we accounted for it when estimating the structural equation modeling (SEM) model. An appropriate way to handle a formative factor approach is to avoid the multicollinearity between the measurement items (Christophersen and Konradt, 2008). We used item-total correlation to exclude some items under the construct. Item-total correlation refers to the correlation between an item or indicator and the composite scores of all items in the same set. The corrected item-total correlation does not include the score of a particular item when calculating the composite score; thus, it is called a correlation (Koufteros, 1999). Some highly relevant measurement items should be eliminated to avoid the correlation leading to the estimation bias of the SEM model.

4.2.3. Perceived usefulness and perceived ease of use

The items used to measure perceived ease of use and perceived usefulness were primarily based on studies relevant to the TAM (Davis, 1989;Gefen et al., 2003; Gefen and Straub, 2004; Moon and Kim, 2001; Featherman and Pavlou, 2003; Yu et al., 2005). Furthermore, some items related to mobile commerce adoption intention were included based on the studies of Kuo and Yen (2009), Kim and Gupta (2009), and Kim et al. (2007). According to previous studies on the utilization of mobile technologies, convenience, efficiency, and time saving were adopted as points of inquiry in the present questionnaire (Khalifa and Shen, 2008; Kim et al., 2010; Mallat et al., 2008). Traditional application of the TAM considers the construct of perceived ease of use as if using and understanding the technology in question is easy. In particular, when users are considering adoption of an innovative technology, they are more willing to try it if it is easy to use.

The variable measurements were measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). As a pre-test, the questionnaires were discussed with experts with prior mobile commerce experience in transportation. The final variable measurements used for data collection in this study are shown in Table 2. Five-point Likert scales with endpoints of "strongly disagree" and "strongly agree" were used to measure the adoption intention of HSR passengers. This study uses the maximum likelihood method to estimate the path coefficient, which is not dependent on the scale of measurement. The software LISREL, which was adopted in our study, has "front end" programs that can take ordinal or skewed data and transform them into usable forms.

5. Empirical results

SPSS and LISREL 8.52 software were used to determine our analytical results. A total of 262 usable responses were received and were included in this study. The respondents' experience with using mobile access and QR codes are presented in Table 3. One hundred and seventy-nine respondents had experience using mobile access (68.3%), but only 69 respondents had experience using QR codes (26.3%). Moreover, approximately a quarter of the respondents had no experience with mobile access or with using QR codes.

The respondents' demographic information is shown in Table 4. Table 4 indicates that the number of males (51.9%) was slightly larger than the number of females (48.1%). More than 60% of the respondents were between 18 and 35 years of age. Some elder respondents were unable to evaluate their willingness to accept these mobile technologies because of a lack of knowledge about mobile access and QR codes, making their responses unusable. In terms of educational level, most respondents were educated at the college level or higher (89.7%).

The Taiwan High Speed Rail Corporation (THSRC) has launched several promotional programs to attract younger users to the HSR. The percentage of younger users of the THSR is growing gradually and significantly. We also talked with a senior expert in charge of the marketing strategy at the THSRC, who confirmed that the sample's representativeness is reasonable. Therefore, the sample in our study is considered representative. The analysis results for mobile access and QR codes are separately presented in the following section. SEM is adopted to investigate the acceptance of mobile ticketing technologies.

5.1. Analysis of passengers' acceptance of mobile access

The application of the SEM model addresses a series of interrelated dependence relationships among the measured and latent variables and between several latent constructs. This study aims to examine the various relationships among the constructs: perceived risk, perceived ease of use, perceived usefulness, and personnel innovativeness. Therefore, the application of the SEM model adopts the following assumptions: (1) a reasonable sample size, (2) model identification, and (3) a theoretical basis for model specification and causality. Before applying the SEM analytical method, we examine these assumptions. The scale validation of the measurement items should be examined before proceeding with further analysis.

5.1.1. Scale validation

The scale validation is examined using the following indices: internal reliability, convergent validity, discriminant validity, goodness of fit of the model when using mobile technologies to purchase HSR tickets.

Fornell and Larcker (1981) indicated that item reliability, composite (construct) reliability (CR), and the average variance extracted (AVE) can be used to test the convergent validity of measurements. The analytical results show the test for internal reliability and convergent validity (Table 5). Cronbach's alpha (α) is a commonly used measure for internal reliability (Hair

Table 2
Measure scales of acceptance of the mobile channel.

Construct	Item	Measurements	Reference
Perceived usefulness	MIU1	I think using the mobile Internet to inquire about information or book tickets is more convenient than using other channels	Khalifa and Shen (2008), Kim et al. (2010), and Mallat et al. (2008)
	MIU2	I think using the mobile Internet to inquire about information or book tickets is more efficient than using other channels	
	MIU3	I think using the mobile Internet to inquire information or book tickets is faster than using other channels	
	MIU4	I think using the mobile Internet will make inquiry and booking easier	
	QRU1	I think using QR code is more convenient than using a physical ticket	
	QRU2	I think using QR code is faster than using a physical ticket	
	QRU3	I think using QR code will make ticket pick-up easier	
Perceived ease of use	MIE1	I think learning to use the mobile Internet for inquiry or booking is easy for me	Kim et al. (2010) and Schierz et al. (2010)
	MIE2	I think using the mobile Internet to inquire about information or book tickets is easy for me	
	QRE1	I think leaning to use QR code is easy for me	
	QRE2	I think using QR code is easy for me	
Perceived risk	MIR1	Risk of failure in connection with using mobile access to inquire about information or to book a ticket	Kim et al. (2010) and Mallat et al. (2008)
	MIR2	The personal information's loss because of using the mobile Internet	
	MIR3	The risk that I make errors when booking tickets through the mobile Internet	
	QRR1	The risk of not receiving the QR code ticket or receiving it after a long delay	
	QRR2	The risk of the QR code's billing error	
Behavioral intention	MII1	I will try to use the mobile Internet if necessary in life or in work	Kuo and Yen (2009)
	MII2	If possible, I will try to use the mobile Internet	
	QRI1	I will try to use QR code if necessary in life or work	
	QRI2	If possible, I will try to use QR code	
Personal innovativeness	PI1	I am curious about various things	Kuo and Yen (2009) and Kim et al. (2010)
	PI2	I am always interested in most up-to-date products	
	PI3	I usually purchase the new products	

Table 3
The experience of using the mobile Internet and QR code ($n = 262$).

	The experience of using QR code		
	Yes	No	Total
The experience of using the mobile Internet			
Yes	**52**	**127**	**179** (68.3%)
No	**17**	**66**	**83** (31.7%)
Total	**69** (26.3%)	**193** (73.7%)	**262**

Note: Figures in bold represent frequency, and figures in parentheses refer to percentage.

Table 4
Profile of respondents ($n = 262$).

Group	Frequency	Percentage
Gender		
Male	136	51.9
Female	126	48.1
Age		
18–25	85	32.4
26–35	79	30.2
36–45	30	11.5
46–55	51	19.5
56–65	17	6.5
Educational attainment		
Junior high school or less	2	0.8
High school	25	9.5
College	146	55.7
Post-graduate degree	89	34.0
Monthly income		
⩽20,000 NTD	82	31.3
20,001–40,000 NTD	75	28.6
40,001–60,000 NTD	55	21.0
60,001–80,000 NTD	33	12.6
80,001–100,000 NTD	13	5.0
⩾100,001 NTD	4	1.5
Occupation		
Students	68	26.0
Employment in secondary industries	59	22.5
Employment in tertiary industries	118	45.1
Unemployed or retired	5	1.9
Others	12	4.6

et al., 2006) and one of the most widely used metrics for reliability evaluation (Koufteros et al., 2001). As shown in Table 5, α values exceeding 0.7 indicate good internal reliability (Hair et al., 2006; Tait et al., 2003).

Convergent validity is assessed by using t-tests to examine the significance of individual item loading (Lu et al., 2007). Generally, a standardized factor loading should be at least 0.5 or higher and, ideally, 0.7 or higher (Hair et al., 2006). In this study, all loading estimates meet the requirement level of 0.5. The composite reliabilities (CR) ranging from 0.7492 to 0.8985 exceed the recommended level of 0.7 (Hair et al., 2006). The values of AVE range from 0.5036 to 0.8157, also meeting the requirement of the recommended level of 0.5 (Hair et al., 2006).

Discriminant validity is assessed by comparing the AVE to the squared correlation between constructs. The AVE estimate is a complimentary measure of the measure of composite reliability (Fornell and Larcker, 1981; Koufteros et al., 2001). A successful evaluation of discriminant validity indicates that a test of a concept is not highly correlated with other tests designed to measure theoretically different concepts (Campell and Fiske, 1959). Table 6 indicates that the diagonal elements in the correlation matrix were replaced by the square root of AVE for each construct, and these values are greater than the inter-construct correlations. Thus, the discriminant validity of this study is supported (Fornell and Larcker, 1981).

The goodness-of-fit indices are presented in Table 7. The χ^2 value is 107.224 with 67 degrees of freedom ($p < 0.05$). Previous studies (Lu et al., 2007) showed that the statistical test may be influenced by the sample size or the number of observable variables; therefore, it is much more appropriate to measure absolute fitness using the χ^2 ratio, GFI (goodness-of-fit index), AGFI (adjusted goodness-of-fit index), RMR (root means square residual), and RMSEA (root mean square error of approximation) (Hair et al., 2006; Kim et al., 2010). All of these goodness-of-fit indices are shown in Table 7, and all indices achieve the recommended levels. Moreover, incremental and parsimony fit indices of the research model meet the required standards (NFI = 0.964, CFI = 0.986, PGFI = 0.603, PNFI = 0.709), indicating a good model fit.

Table 5
Internal reliability and convergent validity (mobile Internet).

Construct	Item	Internal reliability	Convergent validity				
		Cronbach's α	Standardized factor loading	Standard error	*t*-Value	CR	AVE
Personal innovativeness	PI1	0.777	0.77	0.41	13.05	0.7994	0.5763
	PI2		0.88	0.22	15.39		
	PI3		0.60	0.64	9.78		
Perceived risk	MIR1	0.739	0.57	0.67	8.83	0.7492	0.5036
	MIR2		0.75	0.44	11.54		
	MIR3		0.79	0.38	12.13		
Perceived usefulness	MIU1	0.852	0.84	0.29	15.99	0.8526	0.5921
	MIU2		0.77	0.41	13.93		
	MIU3		0.76	0.43	13.70		
	MIU4		0.70	0.50	12.39		
Perceived ease of use	MIE1	0.843	0.81	0.34	15.58	0.8466	0.7345
	MIE2		0.90	0.19	15.21		
Behavioral intention	MII1	0.903	0.90	0.19	17.45	0.8985	0.8157
	MII2		0.91	0.16	17.78		

Table 6
Discriminant validity of the research model (mobile Internet).

Construct	PI	PR	PU	PEOU	BI
PI	**0.759**				
PR	−0.190	**0.710**			
PU	0.425	−0.271	**0.769**		
PEOU	0.363	−0.344	0.556	**0.857**	
BI	0.459	−0.317	0.683	0.489	**0.903**

Note: PI – personal innovativeness; PR – perceived risk; PU – perceived usefulness; PEOU – perceived ease of use; BI – behavioral intention. The figures in bold stand for the square root of AVE of each construct.

Table 7
Goodness-of-fit indices of confirmatory factor analysis (mobile Internet). *Source*: Hair et al. (2006)

Fitness index	Index value	Ideal value
Absolute fit measure		
χ^2/df	1.60	<3.00
RMSEA	0.047	<0.08
GFI	0.945	>0.90
AGFI	0.915	>0.90
RMR	0.042	<0.05
Incremental fit measure		
NFI	0.964	>0.90
CFI	0.986	>0.90
Parsimony fit measure		
PGFI	0.603	>0.50
PNFI	0.709	>0.50

Table 8
Results of hypothesis test (mobile Internet).

Path	Estimate	*t*-Value	Result	
Personal innovativeness → behavioral intention	0.18	2.74	H1a	Accept
Personal innovativeness → perceived risk	−0.21	−2.65	H1b	Accept
Personal innovativeness → perceived usefulness	0.25	3.41	H1c	Accept
Personal innovativeness → perceived ease of use	0.38	5.19	H1d	Accept
Perceived risk → behavioral intention	−0.11	−1.86	H3a	Reject
Perceived risk → perceived usefulness	−0.09	−1.36	H3b	Reject
Perceived ease of use → perceived usefulness	0.44	5.99	H4a	Accept
Perceived ease of use → behavioral intention	0.10	1.45	H4b	Reject
Perceived usefulness → behavioral intention	0.52	6.74	H5a	Accept

χ^2 = 121.926, df = 68, *p*-value = 0.000, GFI = 0.939, AGFI = 0.906, RMSEA = 0.0532, CFI = 0.981.

5.1.2. Path coefficient of the mobile access acceptance model

Because model fitness has been confirmed, the proposed hypotheses can be tested using SEM. This study adopts a maximum likelihood method for its parameter estimation. Table 8 shows the goodness-of-fit measures of the structural model. The χ^2 value is 121.926 with 68 degrees of freedom ($p < 0.001$). The RMSEA is 0.0532, the GFI is 0.939, the AGFI is 0.906, and the CFI is 0.981. These indices imply an acceptable model fit for the structural model.

Fig. 4 and Table 8 show the test results. Except for H3a, H3b, and H4b, the other hypotheses are accepted. Our analytical results show that personal innovativeness has positive effects on perceived usefulness ($\beta = 0.25$, t-value = 3.41, $p < 0.001$), perceived ease of use ($\beta = 0.38$, t-value = 5.19, $p < 0.001$), and behavioral intention ($\beta = 0.18$, t-value = 2.74, $p < 0.01$). Thus, H1a, H1c, and H1d are accepted. These results are consistent with previous research (Kuo and Yen, 2009; Yang, 2005; Bigné-Alcañiz et al., 2008; Kim et al., 2010). That is, passengers who are willing to try new things perceive mobile access to be useful and easy to navigate. Moreover, innovative passengers are more willing to adopt mobile access to search for THSR information or make reservations, and the analytical results reveal that personal innovativeness has a negative influence on perceived risk ($\beta = -0.21$, t-value = -2.65, $p < 0.01$). Therefore, H1b is accepted, which is consistent with the findings of Aldás-Manzano et al. (2009). Personal innovativeness may well reduce passengers' perceived risk of using mobile access. The negative influence of perceived risk on perceived usefulness ($\beta = -0.09$, t-value = -1.36, $p > 0.05$) and behavioral intention ($\beta = -0.11$, t-value = -1.86, $p > 0.05$) is as expected, but is not statistically significant. Thus, H3a and H3b are rejected. A possible explanation is that respondents are expected to navigate the THSR website through mobile access only for information inquiries and reservations, which does not present a great risk of financial loss. Therefore, in this study, the effect of perceived risk on perceived usefulness and behavioral intention is insignificant.

The influence of perceived ease of use on perceived usefulness ($\beta = 0.44$, t-value = 5.99, $p < 0.001$) is accepted, in agreement with previous studies (Ahn et al., 2004; Kuo and Yen, 2009; Bigné-Alcañiz et al., 2008; Wu et al., 2011). The positive effect of perceived ease of use on perceived usefulness (H4a) indicates that if passengers believe that it is easy to become familiar with using mobile access, they are more likely to perceive it to be useful. However, this study did not accept the effect of perceived ease of use on behavioral intention (H4b). With regard to the relationship between perceived usefulness and behavioral intention, H5a is accepted ($\beta = 0.52$, t-value = 6.74, $p < 0.001$), implying that the acceptance intention increases when passengers believe that mobile access is useful. Furthermore, Wu and Wang (2005) demonstrated that perceived ease of use indirectly affects behavioral intention through perceived usefulness in terms of the adoption of mobile commerce.

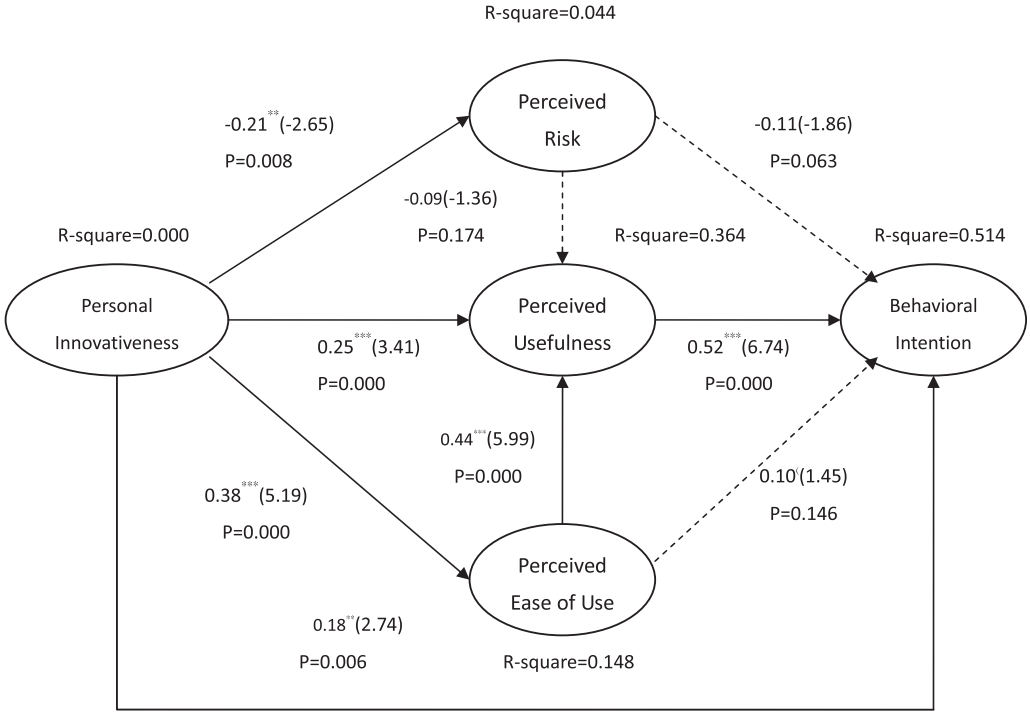

Fig. 4. Structural model (mobile access) $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 9
Internal reliability and convergent validity (QR code).

Construct	Item	Internal reliability	Convergent validity				
		Cronbach's α	Standardized factor loading	Standard error	*t*-Value	CR	AVE
Personal innovativeness	PI1	0.777	0.81	0.35	14.18	0.7955	0.5707
	PI2		0.85	0.28	15.06		
	PI3		0.58	0.66	9.54		
Perceived risk	QRR1	0.772	0.84	0.29	13.71	0.7714	0.6287
	QRR2		0.74	0.45	12.07		
Perceived usefulness	QRU1	0.884	0.83	0.31	15.99	0.8824	0.7144
	QRU2		0.86	0.27	16.67		
	QRU3		0.85	0.28	16.50		
Perceived ease of use	QRE1	0.887	0.88	0.23	16.96	0.8866	0.7963
	QRE2		0.91	0.18	17.78		
Behavioral intention	QRI1	0.933	0.95	0.10	19.65	0.9333	0.8749
	QRI2		0.92	0.15	18.66		

Table 10
Discriminant validity of the research model (QR code).

Construct	PI	PR	PU	PEOU	BI
PI	**0.755**				
PR	−0.311	**0.793**			
PU	0.535	−0.651	**0.845**		
PEOU	0.577	−0.530	0.706	**0.892**	
BI	0.545	−0.550	0.680	0.669	**0.935**

Note: PI – personal innovativeness; PR – perceived risk; PU – perceived usefulness; PEOU – perceived ease of use; BI – behavioral intention. The figures in bold stand for the square root of AVE of each construct.

5.2. Analysis of passengers' acceptance of QR code

5.2.1. Scale validation

To conduct the scale validation, all estimates of internal reliability and convergent validity are examined to determine whether they meet the model's requirement. The α coefficients all exceed 0.7. The standardized factor loadings, which range from 0.58 to 0.95, meet the ideal level of 0.5. The values of composite reliability and average variance extracted achieve the respective recommended levels of 0.7 and 0.5 (Table 9). Furthermore, the results of discriminant validity are also supported (Table 10).

The goodness-of-fit indices are presented in Table 11. The χ^2 value is 73.921 with 44 degrees of freedom ($p < 0.01$). The absolute, incremental, and parsimony fit indices all achieve the corresponding ideal levels, indicating a good model fit.

5.2.2. Path coefficient of the QR code acceptance model

The parameter estimation of QR code acceptance is also conducted using the maximum likelihood method. Table 12 illustrates the fit measures of the structural model for passengers' QR code acceptance. The χ^2 value is 119.163, with 46 degrees

Table 11
Goodness-of-fit indices of confirmatory factor analysis (QR code). *Source*: Hair et al. (2006)

Fitness index	Index value	Ideal value
Absolute fit measure		
χ^2/df	1.68	<3.00
RMSEA	0.050	<0.08
GFI	0.956	>0.90
AGFI	0.921	>0.90
RMR	0.035	<0.05
Incremental fit measure		
NFI	0.981	>0.90
CFI	0.992	>0.90
Parsimony fit measure		
PGFI	0.539	>0.50
PNFI	0.654	>0.50

of freedom ($p < 0.001$). The RMSEA is 0.078, the GFI is 0.929, the AGFI is 0.880, and the CFI is 0.980. According to Wu and Wang (2006), AGFI > 0.8 is a tolerable standard. Therefore, the fit indices of the structural model of QR code acceptance are deemed satisfactory.

Fig. 5 and Table 12 present the test results and path estimates. All of the hypotheses are accepted in this study. That is, perceived risk, perceived usefulness, and perceived ease of use are verified to have the expected effects on behavioral intention, and these results are consistent with previous studies (Wu and Wang, 2005; Khalifa and Shen, 2008; Aldás-Manzano et al., 2009). The negative effects of personal innovativeness on perceived risk ($\beta = -0.37$, t-value = -5.06, $p < 0.001$) is as expected, thus supporting H2b (Aldás-Manzano et al., 2009). Personal innovativeness has a positive influence on perceived usefulness ($\beta = 0.17$, t-value = 2.22, $p < 0.05$), perceived ease of use ($\beta = 0.61$, t-value = 8.84, $p < 0.001$), and behavioral intention ($\beta = 0.18$, t-value = 2.38, $p < 0.01$). H2a, H2c, and H2d are accepted, as supported by the findings of previous studies (Kuo and Yen, 2009; Bigné-Alcañiz et al., 2008). The path coefficient also shows that passengers with higher innovative characteristics are more likely to use mobile access and QR codes in the ticket purchasing process.

Perceived risk has significant negative effects on behavioral intention ($\beta = -0.16$, t-value = -2.24, $p < 0.05$) and perceived usefulness ($\beta = -0.39$, t-value = -5.45, $p < 0.001$). H3c and H3d are accepted (Ruiz-Mafé et al., 2009). The estimates related to perceived risk on behavioral intention are statistically significant compared with the model in the mobile Internet structural model, which is not statistically significant. Therefore, lower usage of a certain technology might result in lower familiarity and eventually raise respondents' risk perception.

The positive effect of perceived ease of use on perceived usefulness ($\beta = 0.45$, t-value = 6.12, $p < 0.001$) and behavioral intention ($\beta = 0.30$, t-value = 3.69, $p < 0.001$) is supported, as expected. The positive influence of perceived usefulness on behavioral intention is also supported ($\beta = 0.28$, t-value = 3.03, $p < 0.01$). H4c, H4d, and H5b are accepted, as consistent with previous studies (Ha and Stoel, 2009; Ruiz-Mafé et al., 2009). In this study, both perceived ease of use and perceived usefulness are found to be important predictors of behavioral intention. The analytical results show that the absolute value of the path coefficient for the perceived risk of adoption intention is greater than the one regarding perceived usefulness and ease of use of adoption intention.

5.3. Comparisons between mobile access and QR codes

The difference in path coefficients between the two models cannot be easily interpreted because these two models use different methods for measuring mobile access and QR code adoption. The measurement items under the constructs perceived risk and perceived usefulness for measuring mobile commerce are not identical to the measurement items under the constructs perceived risk and perceived usefulness for measuring QR code use because these two models measure the different stages of the ticket purchasing process, namely, purchasing the HSR ticket and enquiring the HSR service.

When comparing the two models to investigate the acceptance of mobile access and QR codes, a difference in the influence of perceived ease of use on behavioral intention is observed. Perceived ease of use can affect the decision of an HSR passenger to adopt QR codes; however, the cause–effect relationship between the perceived ease of use and the decision of an HSR passenger to adopt mobile access is not statistically significant. This finding implies that a passenger's previous use experience affects his or her decision to adopt new technology. In our survey, most respondents have more use experience with mobile access than with QR codes. For users with more experience using a certain technology, the effect of perceived ease of use is less critical to the adoption of a specific technology service.

Prior studies indicated that the relationship between personal usage experience and personal innovativeness is correlated when evaluating the user's adoption intention towards the information products (Franke and Shah, 2003; Lüthje, 2004; Yu and Gupta, 2009). In our model, the construct "personnel innovativeness" was included and the correlation between the passenger's previous usage experience and the personnel innovativeness should be avoided. Therefore, the passenger's previous experience was not incorporated in our model.

The R^2 of the structural mode (mobile access) and the QR model are 0.514 and 0.546, respectively. The magnitude of R^2 indicates that the extent to which perceived risk, perceived ease of use, perceived usefulness, and personal innovativeness

Table 12
Results of hypothesis test (QR code).

Path	Estimate	t-Value	Result	
Personal innovativeness → behavioral intention	0.18	2.38	H2a	Accepted
Personal innovativeness → perceived risk	−0.37	−5.06	H2b	Accepted
Personal innovativeness → perceived usefulness	0.17	2.22	H2c	Accepted
Personal innovativeness → perceived ease of use	0.61	8.84	H2d	Accepted
Perceived risk → behavioral intention	−0.16	−2.24	H3c	Accepted
Perceived risk → perceived usefulness	−0.39	−5.45	H3d	Accepted
Perceived ease of use → perceived usefulness	0.45	6.12	H4c	Accepted
Perceived ease of use → behavioral intention	0.30	3.69	H4d	Accepted
Perceived usefulness → behavioral intention	0.28	3.03	H5b	Accepted

$\chi^2 = 106.520$, df = 45, p-value = 0.000, GFI = 0.938, AGFI = 0.892, RMSEA = 0.0711, CFI = 0.984.

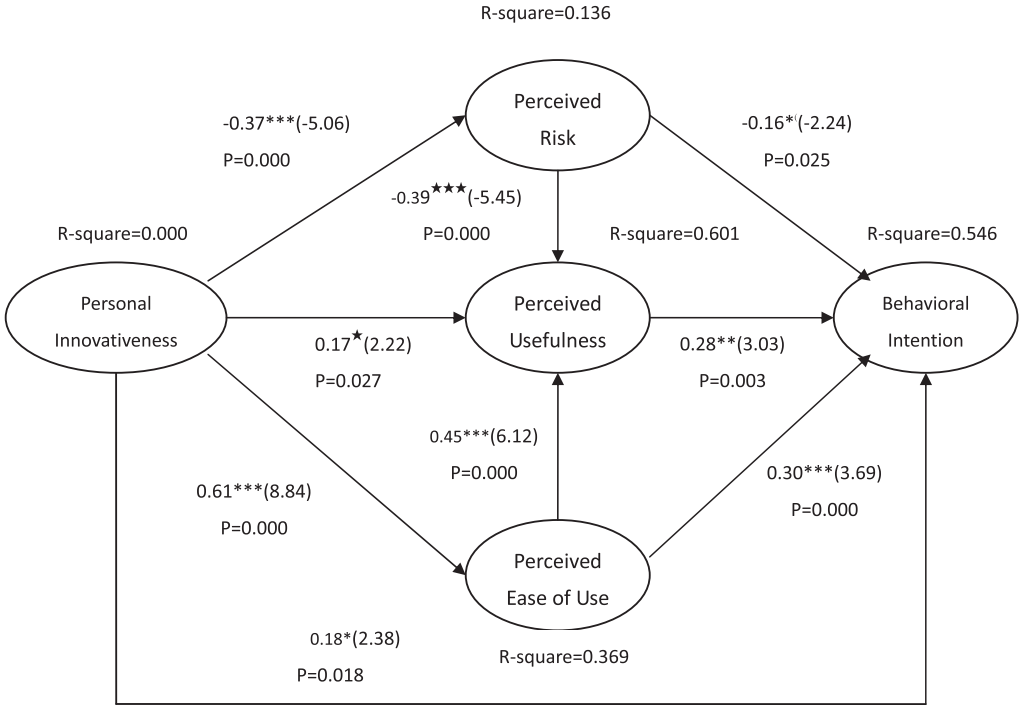

Fig. 5. Structural model (QR code) $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

account for the percentage of the variance in an HSR passenger's adoption intention toward mobile ticketing technology. The R^2 value of these two models demonstrates the appropriate explanatory power of our models in explaining HSR passengers' adoption intention toward mobile ticketing technology.

In the model for measuring mobile commerce, the path of perceived risk on behavior intention, perceived risk on perceived usefulness, and perceived ease of use are demonstrated to be not statistically significant. The perceived risk is not associated with a user's intention when using a mobile service for ticket information searching and ticket reservations. The analytical results show that HSR passengers are not very concerned with security risk, personal information loss risk, and product risk when using the mobile access compared with the ticket purchasing service. The reason for this lack of concern is that HSR passengers believe that mobile access cannot lead to a disclosure of personal information. In contrast, the empirical findings of the conceptual model for examining HSR passengers' QR code adoption indicates that all t-values of the path estimate are statistically significant and not equal to zero, and $\alpha = 0.05$, implying that all measurement constructs, such as perceived risk, perceived ease of use, perceived usefulness, and personal innovativeness affect a passenger's adoption of QR codes.

6. Conclusions and discussions

The major contribution of this research is the integration of mental accounting theory and the technology acceptance model in analyzing HSR passenger adoption of mobile ticketing technology. Drawing on mental accounting theory, mobile ticketing adoption is influenced by the potential loss (perceived risk) and benefit (perceived ease of use and perceived usefulness) of the mobile ticketing service. By understanding the interrelationships between the two main constructs and the interactions between positive and resistance factors, HSR operators may be able to develop appropriate mobile ticketing deployment strategies.

This study examines mobile access and QR code adoption. Differences in the influence of perceived ease of use on behavioral intention of these two mobile ticketing services are also observed. The analytical results provide empirical evidence that a combination of mental accounting theory and the TAM is appropriate to explain passengers' decision to adopt mobile ticketing services. The study demonstrates that perceived usefulness, perceived ease of use, and perceived risk together affect HSR passengers' QR code adoption. In contrast, with regard to mobile access, the negative effect of perceived risk on perceived usefulness and behavioral intention are found to be insignificant. The positive influence of perceived ease of use on behavioral intention is also found to be insignificant. In addition, passengers with higher innovative characteristics are found to be more likely to use mobile access and QR codes in the ticket purchasing process (Aldás-Manzano et al., 2009; Gao et al., 2010). For users with more experience with a certain technology, the effect of perceived ease of use is less critical. In other words, when passengers have experienced using mobile access, they tend to believe that it is easy to learn how to use this

tool and pay more attention to its usefulness. In contrast, passengers who have never used a QR code are more willing to try the new mobile channel if they believe that getting familiar with its usage is easy.

Mental accounting theory has been less frequently used in previous studies on mobile ticketing adoption. Gupta and Kim (2010) indicated that the constructs related to usage benefits were found to have a direct and positive influence on usage intention. This finding is consistent with the findings of our research (except for an insignificant relationship between perceived ease of use and behavioral intention in the findings of acceptance of the use of mobile access). However, Gupta and Kim's study (2010) revealed that perceived risk does not have a direct effect on usage intention, which is contrary to the findings of this research. The reason for the inconsistent results between our study and Gupta and Kim's study may be that respondents' different perceptions of uncertainty lead to perception distinction of perceived risk. The QR code mobile phone application is rarely used in a local context, indicating that HSR passengers believe that perceived risk is a significant determinant that affects consumer adoption given a higher perception of uncertainty.

Compared with previous studies that combined the TAM and perceived risk (Pavlou, 2003), our study is based on mental accounting theory and the TAM to examine the interaction between the positive construct and the negative construct on HSR passengers' mobile ticketing adoption. The empirical findings demonstrate that perceived risk not only directly affects passengers' mobile ticketing adoption but also influences passenger acceptance through the construct of ''perceived usefulness.'' Among the construct of ''perceived risk,'' how consumers perceive ''the risk of not receiving the QR code ticket'' and ''the risk of QR code's billing error'' is considered the principal risk affecting a consumer's decision to adopt. The path coefficient of the analytical results from the SEM demonstrates that, in contrast to the positive benefit, the potential loss seems to be an essential determinant that affects mobile ticketing adoption. Therefore, the designer of a mobile ticketing system should attempt to assuage HSR passengers' perceived risk while improving the systems' ease of use and usefulness for these passengers. The analytical results demonstrate that potential loss (perceived risk) not only affects HSR passengers' mobile ticketing adoption but also offsets the influence of the positive construct (perceived ease of use and perceived usefulness) on the HSR passenger's adoption. Indeed, perceived risk is a deterministic factor that affects an HSR passenger's mobile ticketing adoption.

6.1. Managerial implications

Managerial implications derived from the analytical results of this study may help HSR operators in developing mobile channels or in utilizing other related mobile technologies in the near future.

When launching new mobile channels, the HSR system operator should consider prior developments of mobile ticketing technology and users' familiarity with certain technologies. In our application context, HSR passengers are more familiar with mobile access than with QR codes; therefore, the THSR should allow passengers to believe that adopting mobile access to purchase THSR tickets is convenient, efficient, and effortless. Moreover, the perceived risk was demonstrated to be a significant factor that affected the HSR passenger's QR code adoption when using the mobile ticketing service. The amelioration of perceived risk seems to be the first priority for HSR operators in deploying maximum use of mobile ticketing technology. The THSR needs to provide passengers with a guarantee of privacy and financial security to enhance the confidence of those choosing to adopt innovative new channels. Furthermore, consumers with more experience using a certain technology have lower perceived risk (Miyazaki and Fernandez, 2001). The use of mobile ticketing in the HSR service should consider a suitable context in case a certain percentage of HSR passengers have more experience using mobile ticketing and lower perceived risk. Compared with the application of QR codes in other industries, HSR passengers need to frequently use the ticket purchasing service through an efficient, risk free, and useful mobile technology. Moreover, hackers able to access information through a QR code could steal bank and credit card information and personal information, such as ID numbers and other pertinent personal data. Therefore, the user's concern regarding potential financial loss and personal information disclosure should be the first priority to be ameliorated. Managers should design certain compensation rules for HSR passengers in case of financial losses and personal information disclosure when using the QR code service.

When introducing QR codes as a kind of intangible ticket, the THSR should convince passengers that using QR codes is easy and should encourage passengers to make their first attempts to use a QR code. The THSRC can provide incentives to encourage HSR passengers to use QR codes, such as ticket price discounts or promotions to business class when sufficient traveling distances are accumulated from using QR codes. In both research models—for mobile access and for QR codes—passengers with higher innovative characteristics were more likely to use them in the ticket purchasing process. Special services, such as providing foods and drinks on the train, can be offered. The HSR system operator can derive a suitable deployment strategy for certain groups of passengers with specific characteristics based on the results of this trial use.

6.2. Limitations and future research

Although this study provides insights into consumers' decision to adopt mobile ticketing technology, several limitations warrant further research. This study examines HSR passengers' perspective to recognize their decision to adopt mobile ticketing technology. In terms of developing an innovative ticketing system based on using QR codes, this study is not able to provide a cost–benefit analysis of the construction of such a system given the lack of information from the HSR operator.

6.2.1. Future research

This study examines HSR passengers' QR code service adoption by using self-reported data from HSR passengers. Future studies can use more objective data obtained from passenger QR codes during the trial stage to compare the difference between the self-reported data and the objective data in order to identify the possible reasons for these differences. Moreover, future research can perform a longitudinal and cross-section study to investigate consumers' adoption decisions under various contexts in order to derive market-segmented mobile ticketing deployment strategies. Finally, future studies should conduct a financial feasibility analysis of launching this innovative mobile ticketing technology.

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