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Factors influencing users' employment of mobile map services

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ABSTRACT

This study introduces an integrated research model to examine user acceptance of mobile map services, hypothesizing potential causal connections between key cognitive factors and users' intention to use the services. This study determined potential variables that may be significantly related to perceived usefulness of mobile map services through in-depth interviews with two groups: a user and an expert group. Collected data of 1109 users who took part in the internet survey were analyzed using structural equation modeling. The results indicate that satisfaction with and perceived usefulness of the mobile map services were the most significant antecedents of users' attitude toward the services and behavioral intention to use them. Users' attitude and flow state also affected their intention to use the services, while perceived locational accuracy, service, and display quality had notable effects on attitude. This study demonstrates the significant effects of these and other examined factors, and the findings reveal that *flow* played a multiple moderating roles significantly affecting various connections in the integrated research model. Both theoretical and practical implications are discussed.

1. Introduction

In ubiquitous environments, mobile map services are one of the most widely and frequently used mobile technologies. Commonly, because mobile map services are used in mobile devices such as smartphones and tablet PCs, they are considered as one of the best geographic information systems (GIS) with the advantages of both GIS and mobile technologies (Park et al., 2012; Weiser, 1991). Because providers present photos and pictures taken from various viewpoints via satellites, automobiles, etc., users of the mobile map services can see anywhere (Oulasvirta et al., 2009).

Mobile devices have become the most pervasive device in the modern world. The global popularity of mobile devices is still growing at a high rate. The International Telecommunication Union (ITU) estimated that there are about 6.8 billion mobile cellular subscriptions (MobiThinking, 2013). With this growth in subscriber base, the number of mobile map services available in mobile devices has been rapidly increased (Park et al., 2012). For example, over 150 million users have activated one of the most well-known mobile map services, Google Map service (Engadget, 2011; Google Inc., 2012). However, despite the wide-spread use of mobile map services, little research has focused on users' acceptance and behaviors regarding mobile map services.

Therefore, the current study aims to investigate users' perceptions of mobile map services by exploring external characteristics of the services based on a well-known model in information systems, the Technology Acceptance Model (TAM; Davis, 1989). This study introduces a new integrated model that can be applied to mobile technologies and geographic information systems to explain user acceptance of the services. Employing the model, this study proposes and validates that two user-related factors, perceived locational accuracy and processing speed, affect mobile map services acceptance. A

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well-known statistical method, structural equation modeling (SEM), is used to test the conceptual relational model of the consequences and determinants of user attitude toward mobile map services. SEM analysis also provides the levels of convergent and discriminant reliability of the proposed model. To test the conceptual relationships of the model, this study considers a user-related aspect of mobile map services usage to highlight mobile user dimensions in exploring and identifying the principal factors affecting the use of mobile map services.

This study has the following research question: What user-related factors can drive their intention to use mobile map services? In addressing this question, this study aims to assess the roles of locational accuracy and processing speed in users' adoption of mobile map services. Park et al. (2012, 2013) indicated that increased accuracy of geographic information systems increases people's intention to use them. In addition, several previous studies found that there are positive relationships between processing speed and users' perceived usability of mobile technologies (Park and del Pobil, 2013).

The present study considers this assertion and highlights specific user factors of mobile map services usage to make the findings of interest to both industrial and academic researchers. The present study can contribute to the development of mobile technologies by providing new understandings of important concepts.

Academically, this study clarifies the key influence of perceived usefulness (PU) on users' attitude and intention to use mobile map services. Although a large number of prior studies have explored a variety of variables that generally lead users to adopt mobile services and geographic information systems, few have tried to identify particular user-related factors. The current study addresses this gap by investigating users' perceptions of locational accuracy and processing speed in mobile map services. It explores new factors and structural connections with other factors. Perceived locational accuracy and processing speed along with perceived service and display quality are employed as new concepts that can reflect particular features of mobile map services in ubiquitous environments.

In addition, recent research effort in this area is expected to provide useful information for industry to improve services evaluation of potential adoptions of mobile services and newly introduced geographic information systems. Many industry practitioners see great business opportunity in mobile applications with geographic information services and are confident that it will develop into a strong market segment in a near-term future. Research is essential to guide the industry toward success. The proposed user-acceptance model seemed to be well-suited for developing a user framework, because mobile devices and applications are one of the most frequently-used items in these days (Shin et al., 2011). In addition, this study suggests that improving the factors in the integrated model that predict successful adoption or failure of new businesses is an important consideration.

The remainder of this paper is organized as follows. First, a literature review and a description of previous studies of mobile map services are provided. Then, the hypotheses and research model are proposed. The research methods used in the current study are explained, and the statistical results are presented. Finally, discussion and conclusions of this study are provided, its limitations are described, and guidelines and directions for future study are presented.

2. Mobile map services

The underlying technologies for mobile map services should incorporate and integrate two or more engineering technologies. The general basic mobile map service architecture is shown in Fig. 1 (Chow, 2008). First, a stable mobile system that

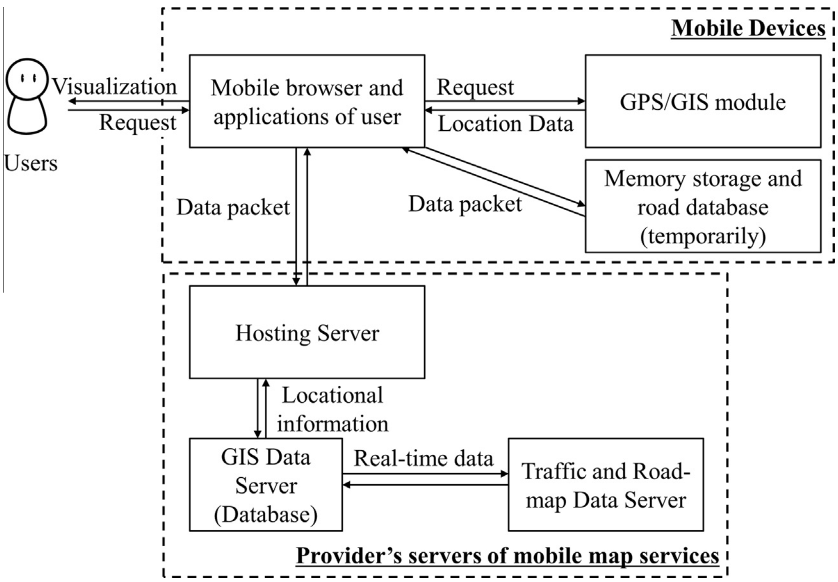

Fig. 1. The general architecture of basic mobile map services.

includes a roads-database and memory storage is required. Stable hardware and software are essential. Second, modules for wireless communications such as GPS, 3G and wi-fi connections should be included to deliver the users' locational data (Chow, 2008). In addition to these technologies, a large number of sub-technologies are employed to provide mobile map services.

From the users' perspectives, there are two important issues in using mobile map services. First, a visualization method and distance measurements are needed to deliver accurate traffic and road map information. Second, real-time synchronization, approximate feedback, and system integration are required to send/receive the right data at the precise time (Ariyoshi et al., 1988; Narzt et al., 2004; Robertson and Cipolla, 2004; Gilliéron and Merminod, 2003).

In recent years, a high-level of R&D (Research & Developments) effort in the mobile map services translated into dramatic improvements in usability and features of the services. First, a large number of companies of mobile map services have introduced the new types of maps for raising the degree of users' satisfaction (Oulasvirta et al., 2009). Compared to 2D-based mapping visualization found in early version of mobile map services, 3D-based mapping applications contained significant enhancements, like Google Earth for personal computers that was developed and introduced in 2008 (Google Inc., 2008). Microsoft also introduced 3D location-view services for personal computers around the same time. Shortly afterwards these companies introduced their mobile map service-applications mounted with 3D visualization functions. After the introduction of 3D display technologies for online maps, a large number of companies which provide mobile map services have provided 2D and 3D-based mobile map services (Google Inc., 2013a,b).

In addition to 2D and 3D-based display maps in mobile map services, mobile map services companies have used other kinds of images and pictures to provide accurate and convenient locational information. For example, we can use mobile map services (e.g. Google Maps) in a bird's-eye view as provided by satellites and air planes (Google Inc., 2013a).

Second, diverse locational contents can be provided via mobile map services. By connecting consumer-level search sites, mobile map services are able to visualize the results of searching on the mobile maps. A large number of popular mobile map services have provided essential features to improve users' satisfaction in using the services. According to Geller (2007), the majority of online map services (including their mobile version) have provided the following features:

- Moving directions between two addresses.
- User interface for navigation.
- Connection and integration with a searching database including local information.
- Zoom-in and out function from narrow level to national level.
- Satellite and air-plane view, displaying landscape features from overhead.
- Access to lots of information visualization levels such as displaying traffic situation.

Because a large number of mobile map services companies provide a user-customized feature for mobile map types, users of the services can see a variety of useful information including traffic status, public transportation information, and accommodation information provided by high-quality rendering technologies (Lee et al., 2008).

One of the most successful examples is Google Maps. Google Maps for the mobile environment debuted in November 2007, and now over 150 million users are employing Google Map service as a mobile application (Engadget, 2011; Google Inc., 2012). Through the 3G or Wi-Fi connections provided in mobile environments, Google Map services provide stable mobile map services using integrated technological solutions.

Now, the majority of companies in the mobile market provide mobile map applications for users' mobile devices, such as Google Map Service, and Yahoo maps. For example, Microsoft provides mobile map applications called 'Bing maps' for users of mobile devices (Blog, 2010). This service provides two types of map viewpoints: a street-level view and a bird's-eye view from air planes and satellites, with real street images. MapQuest also provides a free online mobile mapping services for mobile devices via mobile application markets such as Android, Apple app-store, and so on (MapQuest, 2013).

2.1. History of mobile map services

'OpenStreetMap' is considered to be first mobile map service introduced in the industry in July 2004 (Ramm and Topf, 2010). It is a global collaborative project to establish a free online map. Since 2004, many large companies and universities – Yahoo, Automotive Navigation Data, Google Inc., and Oxford University – have supported this project. They used the data and results from this collaborative project to provide better mobile map data and services (Batty, 2007; Fossum, 2012; Willis, 2007). In addition, more than 150,000 contributors from 600,000 registers have partaken in this project in 2013 (Neis, 2013).

Globally, Google Inc. provides two types of electronic map services in the mobile environment: Google Earth and Google Maps (Google Inc., 2013a,b). Following its first commercial announcement of Google Maps in 2005 for online users, the company announced mobile services in November 2007 (Miller, 2006; Vandenburg, 2008). In 2011, over 150 million users were employing Google Maps via their mobile devices (Engadget, 2011; Google Inc., 2013a).

Google Earth is an online geographical information service that provides multiple viewpoints of locations (Vandenburg, 2008). By using images and data from satellites, GIS 3D systems and technologies and airplanes, Google Earth provides users with numerous overhear views. The first commercial version of Google Earth was introduced by Google Inc. and the Central Intelligence Agency in 2004, and they introduced the mobile version in 2008. In 2011, the mobile version of Google Earth was downloaded over a billion times (Google Inc., 2012).

Another successful version of mobile map services is MapQuest mobile, provided by MapQuest (2013). MapQuest mobile provides global online map services. One of the most highlighted characteristics of MapQuest mobile is its real-time traffic condition-display and real street-level images (MapQuest, 2013). Since MapQuest first introduced mobile services in 2004, it has gained much popularity with over 39 million users reaching the service on their mobile devices in September 2011 (MapQuest Company, 2011).

3. Theoretical background & hypotheses

3.1. Modeling driver acceptance of mobile map services

Predicting and evaluating user acceptance of particular technologies and services has been a hot field of both industrial and academic research in recent years. Many theoretical attempts to predict users' perceptions of particular services and systems have been proposed. Among these, the technology acceptance model (TAM) introduced by Davis and his colleagues is widely regarded as the most successful model for explaining how people form their opinions, use, and accept particular services or technologies (Davis, 1989; Davis et al., 1989). Especially, prior studies have attempted to use this model to explain geographic information systems, mobile devices, and mobile technologies. For example, Cheong and Park (2005) employed it to analyze user acceptance of mobile applications and geographic information services. The TAM has also been used to elucidate the process by which users employ particular services in various fields (including mobile technologies and geographic information services) for mobile devices (Qi et al., 2009), mobile learning (Shin et al., 2011), and mobile applications for internet map services (Eriksson and Strandvik, 2009). Given the success of the TAM in explaining users' perceptions of particular services, this study used it as a main model in a conceptually integrated model for predicting and measuring users' perspectives toward mobile map services.

The original TAM has four constructs. Among them, two psychological beliefs, perceived usefulness and ease of use, act as mediators between two other variables in the TAM: unique characteristics of information systems and users' attitudes and intention to use them. That is, when unique characteristics of particular systems and services have significant effects on two psychological beliefs in the TAM, these beliefs in turn determine users' intention and attitudes toward using the services and systems (Davis, 1989). Davis (1989) defined the construct, perceived ease of use, as "the degree to which people believe that using a particular system or service could be free from their effort." He defined perceived usefulness as "the degree to which people think that their job performance can be enhanced by a particular services and system" (Davis, 1989; Davis et al., 1989). Attitude is "the people's preference when they utilize a particular system or service" (Davis, 1989). Intention to use is "the degree of the psychological state of the people's general minds to use specific services and systems" (Davis et al., 1989).

A great deal of prior research has supported the positive relationships between perceived ease of use and usefulness, perceived ease of use and attitude, perceived usefulness and attitude, perceived usefulness and behavioral intention to use, and attitude and behavioral intention to use, as presented in Fig. 2 (Davis, 1989; Davis et al., 1989). However, several previous studies have indicated that perceived ease of use should be excluded from a user acceptance model for a particular technology or service because perceived ease of use often decreases the reliability and validity of a research model for mobile technologies (Cheong and Park, 2005; Shin et al., 2011). Therefore, the present study proposes an acceptance model of mobile map services that includes the other three constructs of the original TAM. Based on prior TAM research, the current study hypothesis:

- H1: Attitude (towards mobile map services) is positively associated with intention to use (the services)
- H2: Perceived usefulness (of mobile map services) is positively associated with intention to use (the services).
- H3: Perceived usefulness is positively associated with attitude.

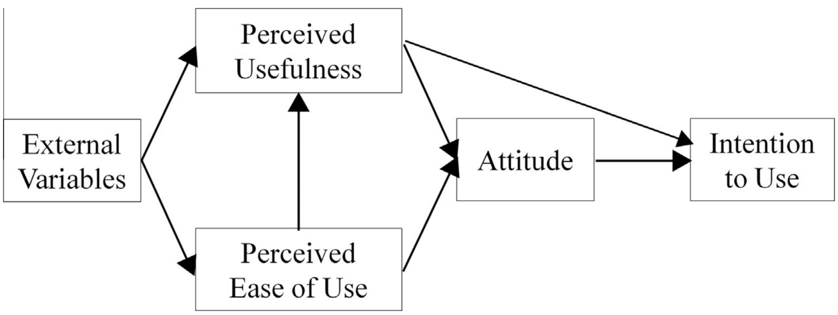

Fig. 2. The original technology acceptance model.

In addition, this study employs four external factors (service and display quality, satisfaction, perceived locational accuracy, perceived mobility, and flow state) that may significantly contribute to users' perceptions of mobile map services. The following sections explain how this study employed these factors and examined their effects on user perceptions of mobile map services.

3.2. Perceived locational accuracy (PLA)

When we use GPS services, displayed locational information is one of the most essential parts. The current study uses the description of perceived locational accuracy explained by Park et al. (2012, 2013), which they defined as "the degree to which users of mobile map services are becoming aware of their exact locations in displayed maps". Users of mobile map services are able to see their current locations and related environments in the maps. In addition, because the majority of mobile map systems in mobile devices provide their services in real-time, the systems and services should present accurate locations of users by calculating and providing locational information immediately. Hence, the better the locational accuracy and efficiency of mobile map systems and services, the more valuable users are likely to believe the systems and services to be. Therefore, this study hypothesizes:

- H4: Perceived locational accuracy (of mobile map services) is positively associated with their perceived usefulness (of the services).
- H5: Perceived locational accuracy (of mobile map services) is positively associated with attitude (toward the services).

3.3. Satisfaction (ST)

A large number of prior studies have reported a generally positive relationship between users' perceived satisfaction and usability of information systems and mobile technologies. For example, Liaw et al. (2006) found that users' perceived satisfaction in using assistive services is positively associated with their perceptions of the usability. Related to geographical information systems, Park and his colleagues found that perceived satisfaction was a notable determinant of users' behavioral intention to use systems, such as car navigation systems (Park et al., 2012, 2013). Therefore, based on the prior studies, this study hypothesizes:

- H6: Satisfaction (with mobile map services) is positively associated with intention to use (the services).
- H7: Satisfaction is positively associated with attitude.

3.4. Service and display quality (SDQ)

The term *quality of service* was first introduced by DeLone and McLean (1992). It is defined as "the degree of general performance of an information system and related services." Prior studies related to information systems have demonstrated a strongly positive connection between service quality and users' perceptions of that service, its technologies, and the enclosed systems. For example, Lin and Hsieh (2006) showed that quality of particular service technologies was positively connected to users' intention to use them. Similarly, Ahn et al. (2004) found that service quality is a significant antecedent to using particular online services and technologies. Given that mobile map services have both a service characteristic (i.e., mobile OS and devices) and a display characteristic (i.e., user interface and mobile panel), they can be considered together in one construct. Prior studies of viewing quality have supported a positive connection between users' perception of particular information systems and viewing quality (Kim et al., 2011). Therefore, the current study hypothesizes:

- H8: Service & display quality (of mobile map services) is positively associated with satisfaction (with the services).
- H9: Service & display quality is positively associated with attitude.

3.5. Perceived mobility (PM)

This study uses perceived mobility as a determinant of both satisfaction and perceived usefulness, because perceived mobility is a core factor of any mobile service or application. Prior studies have defined *perceived mobility* as "the degree of user awareness of the portable value of mobile services and systems" (Huang et al., 2007). Related to the mobile context, mobility is defined as the capability to ubiquitously support mobile services through wireless connections. Siau and Shen (2003) explored users' perceived portability as the most significant characteristic in using mobile systems and services. Huang et al. (2007) reported that perceived mobility of mobile devices is a significant antecedent of perceived usefulness of using particular mobile services. Moreover, a large body of prior research on mobile technologies and systems has supported that portability has notable effects on users' perspectives toward mobile services and systems, such as their satisfaction (Gunawardana and Ekanayaka, 2009). Therefore, the current study hypothesizes:

- H10: Perceived mobility (of mobile map services) is positively associated with perceived usefulness.
- H11: Perceived mobility is positively associated with satisfaction.

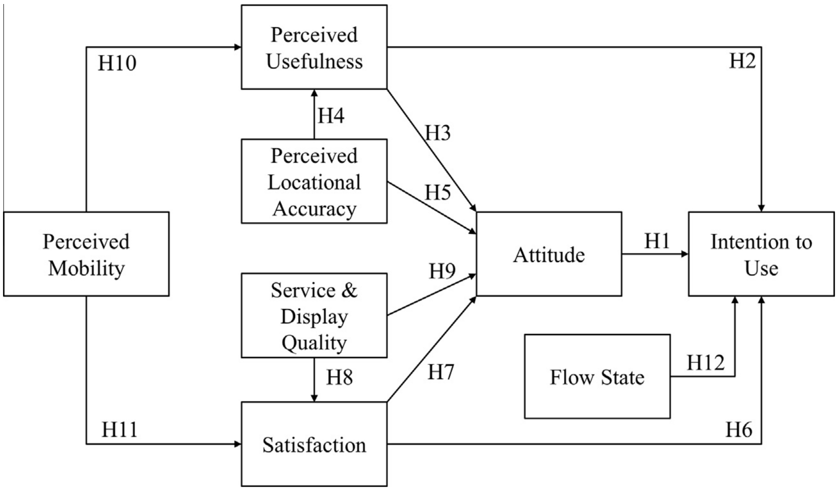

Fig. 3. The research model.

3.6. Flow state (Flow)

Flow is defined as "the mental state of processes in which person is fully immersed in what he/she is doing characterized by a feeling of energized focus, full involvement, and success in the operation of the activity" (Shin, 2010; Shin and Shin, 2011). When a person uses an interactive object and service, a powerful feeling of being there (immersion) is experienced, which guides exploratory behavior. The general idea of flow in the current study is the user's feeling of immersion in interactions in the mobile environment. Many previous studies have indicated that a feeling of presence or being inside the technology and media is a core performance goal of many information services (Shin, 2010; Nowak and Biocca, 2003). The user feels strongly immersed in the mobile environment for mobile map services when they are tele-present, which is defined as "the users' powerful feeling of being in a virtual space different from where the users' physical body is located" (Shin and Shin, 2011). The flow concept is employed in this study as a construct that is part of the experience of mobile map services.

- H12: Flow state (when using mobile map services) is positively associated with intention to use.

3.7. The research model

Based on the hypotheses, this study proposed the research model shown in Fig. 3.

4. Research methodology

4.1. Study design

We conducted an online survey to collect data, which was used to analyze the introduced hypotheses regarding the constructs in the model. To develop the survey, we followed the steps proposed by Venkatesh and Davis (2000).

1. Identify and define practicable characteristics.
2. Operationalize selected variables.
3. Investigate and demonstrate the reliability and validity of the selected variables.
4. Conduct a pilot test of the survey and analyze data from the test.

Table 1
The results of the in-depth interview results for identifying possible factors.

	Expert group	*N* (%)	User group	*N* (%)
1	Service & display quality	41 (33.1)	Locational accuracy	49 (39.5)
2	Satisfaction	24 (19.4)	Mobility	29 (23.4)
3	Locational accuracy	17 (13.7)	Service & display quality	13 (10.5)
4	Mobility	11 (8.9)	Satisfaction	12 (9.7)
5	Enjoyment	9 (7.3)	Processed speed	9 (7.3)
6	Etc.	22 (17.7)	Etc.	29 (23.4)
Total	From 27 experts	124 queries	From 30 users	141 queries

5. Administer the main online survey.

To identify possible variables, we conducted 10-min in-depth interviews of two groups of individuals: a user group (users of mobile map services) and a professional expert group (developers, engineers, and designers in the field of mobile map services). Based on the results of the interview, we identified several diverse factors that should be considered in investigations of mobile map services usage (Table 1).

Operationalizing the selected factors provided the five factors in the model: locational accuracy, satisfaction, service and display quality, mobility, and flow state.

4.2. Measurement development

The survey consisted of 37 questionnaire items used and validated in prior research. All items were translated from English to Korean and examined by an expert panel including three professors of English, three researchers in communications, and professional translators. After translation, back-translation was conducted to validate the items written in Korean. All items were reviewed and revised by a professional group including six experts in mobile applications and communications. Then, a pre-survey was conducted with 30 professors and researchers who had at least one month of previous experience with using mobile map services. All participants in the pre-survey were asked to clarify any confusing items with the investigator. Cronbach's alphas of all constructs were computed to test the reliability of the items in the pre-survey. Eleven items in the initial questionnaire were excluded, and the remaining 26 items comprised the final survey (Table 2).

4.3. Main survey

Online survey tools were used to conduct the main survey. The main survey web link was posted on the Q&A and discussion sections of three mobile applications sites and three mobile services sites. Filtered data of 1,109 respondents who had at least 6 months of experience using mobile map services (out 2,009 collected samples) were statistically analyzed (Table 3).

Table 2
Questionnaire items used in the main survey.

Constructs	Items	Descriptions	Sources
Perceived Locational accuracy	PLA1	Mobile map services always display accurate location	Park et al. (2012, 2013)
	PLA2	Mobile map services always display accurate location in real-time moving situation	
	PLA3	Mobile map services provide efficient routes and accurate destinations that are where I want to go	
Satisfaction	ST1	Overall, I am satisfied with mobile map services	Lee (2006), Liaw et al. (2006), and Park and del Pobil (2013)
	ST2	The mobile map services that I am using now meet my expectations	
	ST3	I recommend mobile map services to others who intend to use and buy mobile applications	
Service and display quality	SDQ1	Mobile map services and displays of information fully meet my needs.	Ahn et al. (2007), and Lin and Hsieh (2006)
	SDQ2	I have not had any limitations or problems in using mobile map services	
	SDQ3	Mobile map services in mobile devices provide perfect and precise services in line with the purpose of the services	
	SDQ4	I have not had any limitations or problems in watching information displayed by mobile map services	
Perceived mobility	PM1	Mobility is an outstanding advantage of mobile map services.	Huang et al. (2007) and Park and Kim (2013)
	PM2	Mobility makes it possible to get real-time locational data	
	PM3	It is convenient to access mobile map services anywhere at any time	
Perceived usefulness	PU1	I think mobile map services are useful in my job	Davis (1989) and Davis et al. (1989)
	PU2	Using mobile map services increases my productivity	
	PU3	Mobile map services are a beneficial tool in performing my job	
	PU4	Using mobile map services improves my performance and effectiveness at my job	
Attitude	ATT1	I think that using mobile map services is better than using other mobile applications	Davis (1989, 1993)
	ATT2	It is easier and better for me to use mobile map services, as opposed to other mobile applications or geographic information services	
	ATT3	In my view, it is very desirable to use mobile map services, as opposed to other mobile applications or geographic information services	
Flow state	FS1	When using mobile map services, I was intensely absorbed in the services	Nowak and Biocca (2003)
	FS2	I strongly feel that I am inside a different world when using mobile map services	
	FS3	When using mobile map services, I fully control the services	
Intention to use	IU1	I would rather use mobile map services than other mobile applications or geographic information services	Davis (1989, 1993)
	IU2	I am very likely to continue to use mobile map services in my life.	
	IU3	If I can maintain access to mobile map services, then I predict that I will continue to use it	

Table 3
Demographic information of participants in this study (Total N = 1,109).

Age	N (%)	Mobile devices experience	N (%)
18–30	424 (38.2)	Under 1 year	94 (8.5)
31–40	291 (26.2)	1–2 years	339 (30.6)
41–50	193 (17.4)	2–5 years	441 (39.8)
51–60	142 (12.8)	5–10 years	101 (9.1)
Over 60	59 (5.3)	Over 10 years	134 (12.1)
Education		Mobile map services experience	
Middle school	32 (2.9)	1–6 months	77 (6.9)
High school	194 (17.5)	6–12 months	194 (17.5)
College	661 (59.6)	1–3 years	451 (40.7)
Graduate or above	222 (20.0)	Over 3 years	387 (34.9)
Gender			
Male	648 (58.4)		
Female	461 (41.6)		

5. Results

5.1. Descriptive statistics

Descriptive statistics of all constructs are presented in Table 4. All mean values of the constructs were greater than 5.0, which indicates that participants had positive evaluations of mobile map services.

5.2. Analysis methods

This study employed structural equation modeling (SEM) to analyze the proposed hypotheses. LISREL 8.0 was also used for confirmatory factor analysis to investigate the reliability of the constructs and items. This study included 1,109 respondents, meeting the recommendation of prior studies that more than 200 respondents should be used for accurate SEM (Anderson and Gerbing, 1988).

5.3. Reliability and Validity of Measurements

The general fit indices of the measurement model were accepted, except for the χ^2/d.f. ratio (χ^2/d.f. = 5.44, IFI = 0.921, NFI = 0.911, NNFI = 0.904, CFI = 0.939, GFI = 0.901, AGFI = 0.902, SRMR = 0.049, and RMSEA = 0.048; Anderson and Gerbing, 1988; Bentler and Bonnet, 1980; Hoelter, 1983; Seyal et al., 2002; Hair et al., 2006). Values of Cronbach's alpha and composite reliability of the constructs were computed to test the reliability and validity of the measurements. Previous studies have indicated that Cronbach's alpha values greater than 0.70 and factor loading values higher than 0.50 indicate internal and convergent reliability (Cronbach, 1971). Therefore, the present study satisfied the recommended values for reliability (Table 5).

Examining discriminant reliability, previous research of SEM has indicated that the square root of the average variance extracted (AVE) of all constructs should be greater than the correlation values between two constructs. All values met these recommendations for discriminant validity (Table 6).

5.4. Hypothesis testing

This study tested the hypotheses in the research model to investigate structural relationships. The overall fit indices met the recommended levels, except for the χ^2/d.f. ratio (χ^2/d.f. = 5.55, IFI = 0.914, NFI = 0.921, NNFI = 0.929, CFI = 0.933, GFI = 0.941, AGFI = 0.944, SRMR = 0.055, and RMSEA = 0.061; Anderson and Gerbing, 1988; Bentler and Bonnet, 1980;

Table 4
Descriptive statistics of conducted measurements.

Constructs	Mean	Standard deviation
Perceived locational accuracy	5.31	1.12
Satisfaction	5.19	1.31
Service & display quality	5.44	1.01
Perceived mobility	5.29	0.99
Perceived usefulness	5.09	1.15
Attitude	5.32	1.24
Flow state	5.11	1.22
Intention to use	5.15	1.27

Table 5
Internal and convergent reliability.

Construct	Items	Internal reliability		Convergent validity		
		Cronbach's alpha	Item-total correlation	Factor loading	Composite reliability	Average Variance Extracted
Perceived locational accuracy	PLA1	0.929	0.910	0.810	0.899	0.751
	PLA2		0.884	0.805		
	PLA3		0.837	0.832		
Satisfaction	ST1	0.881	0.779	0.728	0.838	0.649
	ST2		0.838	0.819		
	ST3		0.824	0.834		
System & display quality	SDQ1	0.871	0.841	0.821	0.911	0.725
	SDQ2		0.818	0.879		
	SDQ3		0.892	0.895		
	SDQ4		0.811	0.800		
Perceived mobility	PM1	0.899	0.849	0.923	0.914	0.752
	PM2		0.861	0.899		
	PM3		0.798	0.841		
Perceived usefulness	PU1	0.921	0.891	0.894	0.950	0.829
	PU2		0.810	0.881		
	PU3		0.824	0.930		
	PU4		0.809	0.927		
Attitude	ATT1	0.913	0.922	0.951	0.945	0.853
	ATT2		0.844	0.901		
	ATT3		0.851	0.915		
Flow state	FS1	0.844	0.801	0.933	0.947	0.871
	FS2		0.821	0.894		
	FS3		0.766	0.833		
Intention to use	IU1	0.850	0.884	0.903	0.910	0.770
	IU2		0.870	0.901		
	IU3		0.819	0.827		

Table 6
Discriminant results with the square roots of average variance extracted.

	1	2	3	4	5	6	7	8
1. Perceived locational accuracy	0.87							
2. Satisfaction	0.23	0.81						
3. System & display quality	0.41	0.19	0.85					
4. Perceived mobility	0.09	0.32	0.35	0.87				
5. Perceived usefulness	0.22	0.25	0.19	0.51	0.91			
6. Attitude	0.08	0.41	0.45	0.61	0.24	0.92		
7. Flow state	0.29	0.32	0.43	0.29	0.19	0.17	0.93	
8. Intention to use	0.35	0.11	0.15	0.43	0.22	0.16	0.36	0.88

Hoelter, 1983; Seyal et al., 2002; Hair et al., 2006). As summarized in Fig. 4 and Table 7, all proposed causal connections were statistically supported by the results.

PU significantly affected ATT and IU (H3, $\beta = .414$, CR = 17.779, $p < .001$; H2, β=.360, CR = 16.423, $p < .001$). Compared to the moderate effects of ATT and FS (H1, $\beta = .238$, CR = 9.594, $p < .001$; H12, $\beta = .264$, CR = 15.469, $p < .001$), PU and ST had notable effects on IU (H2; H6, $\beta = .400$, CR = 20.017, $p < .001$). Therefore, all proposed hypotheses from the original TAM were accepted.

All proposed connections related to the external factors were also confirmed. PU was significantly determined by PLA and PM (H4, β=.614, CR = 30.974, $p < .001$; H10, $\beta = .433$, CR = 21.835, $p < .001$). Similarly, PM and SDQ had significant effects on ST (H11, β=.487, CR = 19.541, $p < .001$; H8, $\beta = .276$, CR = 11.070, $p < .001$). Among the determinants of ATT, PU had a stronger effect on ATT than on ST, SDQ, and PLA (H2; H7, $\beta = .327$, CR = 17.090, $p < .001$; H9, $\beta = .323$, CR = 17.550, $p < .001$; H5, $\beta = .216$, CR = 9.488, $p < .001$).

Examining the variances of the constructs in the proposed model, we see that PU, ATT, ST, and FS explained 67.7% of the variance in IU, while PU, PLA, ST, and SDQ explained 65.4% of the variance in ATT. Also, 31.3% of the variance in ST was explained by the two constructs, PM and SDQ, while 56.4% of the variance in PU was explained by the two determinants, PM and PLA.

5.5. Supplemental analysis

This study conducted additional SEM analyses according to education level, mobile map services experience, mobile devices experience, age level, and gender to determine whether structural differences or patterns of user-acceptance were

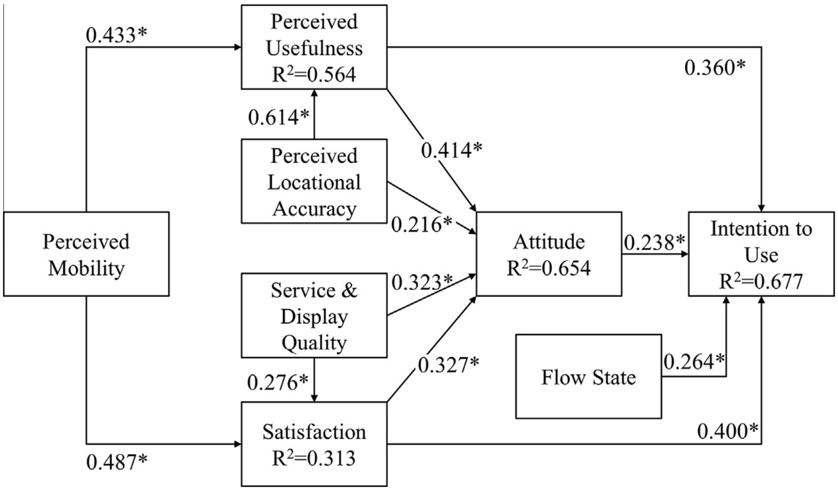

Fig. 4. Results of hypothesis tests; *$p < 0.001$.

Table 7
Results of the hypothesis tests; *$p < 0.001$, ATT = attitude, IU = intention to use, PU = perceived usefulness, PLA = perceived locational accuracy, ST = satisfaction, SDQ = service & display quality, PM = perceived mobility, FS = flow state.

Hypotheses	Standardized coefficient	SE	CR	Results
H1. ATT → IU	0.238*	.025	9.594	Supported
H2. PU → IU	0.360*	.018	16.423	Supported
H3. PU → ATT	0.414*	.019	17.779	Supported
H4. PLA → PU	0.614*	.016	30.974	Supported
H5. PLA → ATT	0.216*	.015	9.488	Supported
H6. ST → IU	0.400*	.015	20.017	Supported
H7. ST → ATT	0.327*	.014	17.090	Supported
H8. SDQ → ST	0.276*	.024	11.070	Supported
H9. SDQ → ATT	0.323*	.013	17.550	Supported
H10. PM → PU	0.433*	.016	21.835	Supported
H11. PM → ST	0.487*	.021	19.541	Supported
H12. FS → IU	0.264*	.012	15.469	Supported

significantly consistent across subjective groups. The results showed that all subgroups had similar patterns of user-acceptance to those observed in the group as a whole.

6. Discussion

This study identified satisfaction, perceived locational accuracy, service and display quality, and perceived mobility as key psychological factors that affect users' perceptions of mobile map services. These elements were identified through in-depth interviews with two groups of mobile map services: experts and users. This study proposed an integrated conceptual model that incorporated the selected factors with a well-known model in information systems, TAM, using three of its constructs to investigate users' acceptance of mobile map services. The statistical results of the structural equation modeling analysis indicate that our proposed model sufficiently and generally explains users' acceptance of mobile map services.

This study finds that SDQ and PLA are the notable determinants of attitude toward mobile map services acceptance. These determinants reveal the current state of mobile map services: (A) Users have concerns about the limited accessibility of mobile map services and about service-quality, and (B) users consider the most significant factor of mobile map services to be whether the services display locational information accurately and distinguishably from the physical surrounding environment (represented by the variable PLA).

Display quality and locational accuracy each influence user attitude, and SDQ has a more powerful effect on attitude than PLA does, suggesting that users weight the service quality and display information more heavily than the development of software and hardware solutions to improve locational accuracy. That is, users are more affected by user-related factors relating to user interface experiences than by technical factors. This finding is a little difference from prior research.

Related to this issue, the current model finds notable roles for PLA and SDQ, while PU and ST also play significant roles in determining attitude. Mobile map services have various unique features that users want to see, and these are more clear

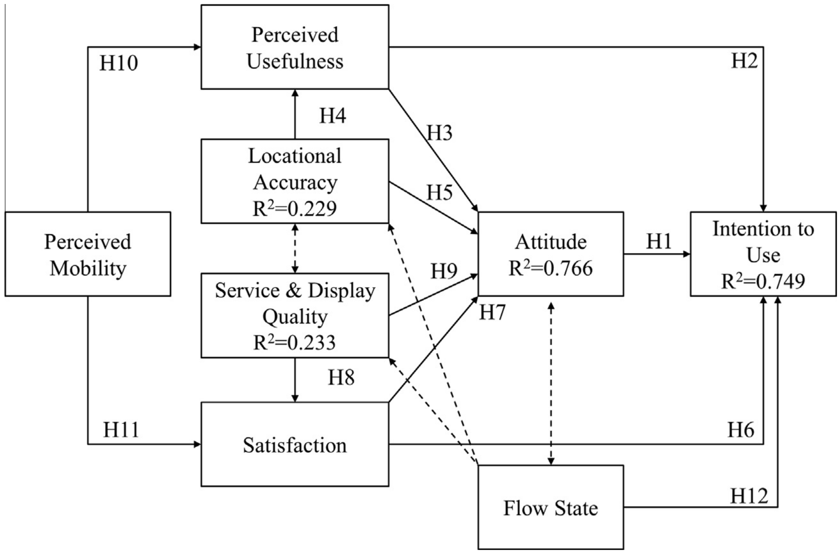

Fig. 5. The extended model with flow state.

motivations than the typically investigated factors, PU and ST. In this study, we found that attitude is determined by these four factors in equilibrium.

The analysis shows that there were antecedents of PU and ST but no determinants of PLA and SDQ in the integrated model. This suggests that it is worthwhile to investigate possible connections with other factors. Therefore, we proposed an extended model to determine the following: (A) the antecedents of PLA and SDQ and (B) the interaction effect between PLA and SDQ. The proposed extended model found a significant role of flow state as a determinant of PLA and SDQ as well as notable interactive connections between PLA and SDQ. The extended model shows a better fit to the data and has better explanatory power than the former proposed model ($R^2 = 0.654 \rightarrow 0.766$ for attitude; $R^2 = 0.677 \rightarrow 0.749$ for intention). This extended model can be a significant theoretical contribution to research in technology acceptance concept and mobile and geographic information system. Prior literature in this area describes initial attempts to determine the antecedents of PU and ST. The proposed research model not only identified the determinants of PU and ST (PLA, SDQ, and PM), but also examined the antecedents of the determinants for PU and ST. It has been observed that flow significantly affects both PLA and SDQ in the extended model (Fig. 5).

The model also indicates that flow clearly enhances intention. This supports the findings of prior studies on flow state. Given that SDQ has significant effects, it is natural to conclude that higher perceptions of service quality result in enhanced feelings of flow state. Prior studies related to flow show that it has significant effects on users' behavioral intention. The current findings expand previous research by clearly identifying the strong connections among flow, PLA, and SDQ in the context of mobile map services. The extended model indicates that flow is significantly connected to perspectives toward locational accuracy and quality of service and display. Not only do the weakly correlated factors PU and ST have significant effects on attitude, flow also significantly affects attitude. And flow has a distinct mediating effect on intention via PLA and SDQ. This mediating effect is remarkably consistent with the findings of Shin and Shin (2011) on the contribution of flow in the online context.

7. Conclusions

Several implications are presented here for researchers of mobile map services as well as for service providers. This study increases understanding of the multi-construct model of PLA, SDQ, and flow. Recent studies on mobile technologies and services have attempted to investigate the factors affecting attitude and their antecedents. Through analysis of the general acceptance of mobile map services, this study introduces PLA, SDQ, and PM as antecedents of PU and ST, which significantly affect attitude and behavioral intention. The findings also indicate the important role of flow, which relates to PLA and SDQ and influences attitude. Although significant prior research has found notable roles of PU and ST in determining attitude toward mobile technologies, few studies have focused on user acceptance of geographic information systems, such as mobile map services.

The academic contribution of the current study lies in its exploration of mobile map services with an improved model of services-specific factors. The current study extends prior research on mobile technologies and geographic information systems by presenting statistical evidence of the utility of the proposed extended model that is based on the technology acceptance concept, demonstrating its application to upcoming ubiquitous environments that include geographic information systems and mobile technologies. The findings indicate that upcoming services should prepare new environments with a user-centered approach for better understanding of mobile user interfaces and experiences. Mobile technologies and geographic information systems, including mobile map services, provide new and interesting opportunities to researchers to apply the technology acceptance concept. The current study can help extend the TAM, as it explains how users choose to employ their devices in mobile environments. Although the TAM has been widely applied to mobile technologies, it has not been comprehensively and widely used for geographic information systems. This study demonstrates the robustness of the proposed model and emphasizes the key roles of locational accuracy and quality of services and display in smooth adoption of mobile map services, contributing to research on the motivations to use mobile map services. The findings of this study suggest the need for future research of the TAM, where the results presented in the current study are complex or not easily verifiable. In addition, this work could provide a deeper and more comprehensive insight of how people use mobile map services. Thus, future research should consider additional motivations and aspects of mobile map services, such as the question: Compared to TAM studies of other mobile technologies, are mobile map services different, and do they relate to a unique concept of user acceptance? It would also be valuable to investigate potential factors such as perceived control and interactivity in upcoming ubiquitous environments. Experts should also examine the direction of causation by investigating changes over time with a long-term period, because mobile map services continuously attempt to respond to users' needs with respect to hardware and software aspects of the services.

Finally, future research analyzing comparative data that focuses on other types of mobile technologies and geographic information systems (e.g., car navigation systems) may provide better understanding of multi-synthetic impacts of mobile and geographic information technologies in ubiquitous environments.

The current study demonstrates the development of a new concept by employing new factors into the TAM. It also shows the application of the concept to understanding the emerging contexts of geographic information systems and mobile technologies.

The industry of mobile map services can incorporate the practical issues of these findings in accordance with future strategies and new business models for mobile and geographic information systems. Until now, the majority of mobile map services have been free to use, but providers of the services will aim to monetize the services as basic applications of mobile devices. To monetize services, it is necessary to conceptually capture users' behavior and reliably provide stable services. Since the current study found that good processing speed and locational accuracy enhance users' perceptions, industry researchers should aim to employ their resources to develop more accurate services as well as to improve users' software interfaces. The findings regarding the diverse roles of satisfaction indicate that providers should establish a conceptual framework of users' satisfaction in mobile map services. Considering the consistently changing environment of the mobile network, the current study supports better understanding of users' behaviors related to mobile map services as well as the development of effective conceptual frameworks to investigate users.

The current study demonstrated that perceived locational accuracy and processing speed were unique characteristics of mobile map services. The results from the SEM showed that PU guides users' attitude and behavioral intention to use the services, while two users' characteristics, perceived locational accuracy and processing speed, enhance users' acceptance toward mobile map services.

This study has shown that all proposed relationships in the research model were supported by empirical analysis. However, there are several unresolved issues that should be addressed in future studies. First, this study did not fully consider individual characteristics as potential covariates. For example, age level and gender of users may have notable effects on their perspectives toward services provided by geographic information systems (Brusque and Alauzet, 2008; Yang, 2005). Therefore, future research should consider additional cognitive characteristics to conceptually explore users' perceptions. Second, social influences and personal innovativeness can affect users' adoption of mobile services. For instance, Lu et al. (2005) found that these factors are significantly associated with the users' adoption of wireless services in using mobile devices. In addition, as shown in previous studies related to flow state (Jung et al., 2009), future studies should focus on the significance of flow state in mobile services including map services. Finally, regional differences may have notable effects on users' intention to use services provided by mobile devices. Considering that mobile map services are more widely-used in developed nations, the usage pattern of mobile map services may be different when these services become available in other regions. Future research should explore these regional differences in order to extend the applicable findings, such as by conducting the survey in multiple nations.

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