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Identification of external variables for the Technology Acceptance Model(TAM) in the assessment of BIM application for mobile devices

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Abstract. With the development of information and communication technology (ICT), various tools designed to utilize the ubiquity of portable devices have been launched. This is also true within the construction industry, where many such tools seek to enhance work efficiency by utilizing ICT and to transform PC-based environments into mobile-based environments to enhance the convenience of use. In accordance with this trend, building information modeling (BIM) has now been extended to portable devices. A number of BIM tools are currently available, such as Formit (provided by Autodesk), BIMx (Graphisoft) and BIMsight (Tekla); however, they are limited to model-related functions such as viewer and model modification. Recently, additional functions such as communication and cloud-based information sharing have been developed, but user-oriented demand research using tools are not yet available. Therefore, based on a literature review, this study summarizes the external variables which affect the use of BIM application tools and describes the expected effects when the relationships between these variables are hypothesized and verified using the technology acceptance model. This study contributes to the development of user-oriented BIM utilization tools for portable devices.

1. Introduction

The use of portable devices in the construction industry has become increasingly common due to continuous advances in information communication technology (ICT; Lee et al., 2015). In particular, building information modeling (BIM) has been the focus of various functional tools based on portable devices. Originally, BIM software such as Revit (provided by Autodesk) and ArchiCAD (provided by Graphisoft) was designed to be used on personal computers. However, to extend usage to mobile devices, a diverse range of applications has appeared (e.g., Formit by Autodesk, BIMx by Graphisoft, and BIMsight by Tekla).

These new programs have typically focused on revising architectural models and displaying the results for viewers. Information sharing based on cloud computing and support services for communication have been added to these applications, but an in-depth analysis of user needs for each of these functions has not yet occurred.

A common tool employed in user need surveys is the technology acceptance model (TAM). The main variables of concern when developing a system is time to market, flexibility, integration, and user satisfaction (Kim, 2015). The TAM defines external variables that can affect user behavior and it can



be have a definition of the requirements of user's view for making system. The TAM has been employed in a variety of areas, including shopping, travel, sports, and the analysis of the organizational acceptance of BIM (Lee et al., 2013). Based on this, it would be efficient demand survey even if it is applied to making BIM tool based on portable devices.

Therefore, the present study conducts a literature review of research related to the development of portable devices in order to analyze the requirements for BIM mobile tools based on the TAM. It also provides the process in which about to external variables for making BIM mobile tools based on time to market, flexibility, and integration. This study thus provides suggestions regarding the requirements for the development of BIM tools and can act as a foundation for further research on this topic.

2. The Identification of External Variables for the TAM

The TAM stems from the theory of reasoned action (TRA). It utilizes the constructs "perceived usefulness" and "perceived ease of use", which are individual beliefs that are affected by external variables. Both of these constructs, in turn, affect "attitude toward using" and "behavioral intentional use" (David, 1989). The TAM is used to represent the mutual relationship between external variables which affect the acceptance of technology by a user and factors which affect actual behavior. This model hypothesizes a relationship between external variables and both perceived usefulness and perceived ease of use. However, because the TAM is founded on individual beliefs, it has a limitation in that social influence is ignored.

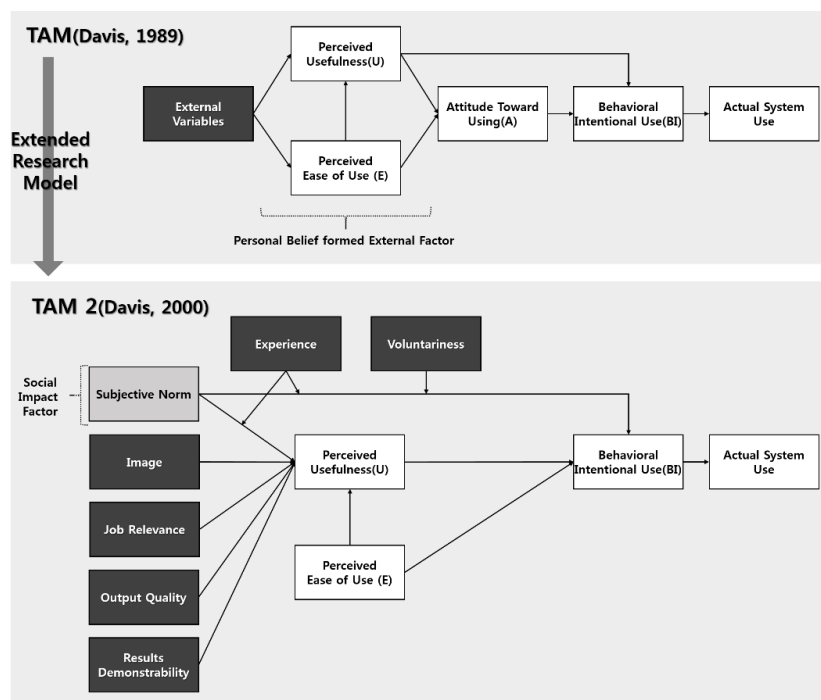


Figure 1. Davis's Technology Acceptance Model(TAM)s (1998,2000)

Due to this limitation, Venkatesh and Davis (2000) introduced the TAM 2 (or ETAM) as an extension of the original TAM. In the TAM 2, attitude is excluded as a variable and subjective norms are added, which is related to social influence, it had ever been deleted (Park, 2012). The TAM 2's external variables are distinguished to both the social influence process and identical tool process. The social process includes subjective norms, voluntariness, and image, while the identical tool process includes job relevance, output quality, and result demonstrability (Song et al., 2011). More recently, the TAM 3 has been proposed, suggesting additional external variables which may affect perceived usefulness

(Venkatesh & Davis, 2008). TAM has been referred to over 4,000 times by various researchers (Lee, 2014).

The development of tools for portable devices is predicated on the following advantages: 1) the possibility of an internet connection anytime and anywhere, 2) the ease of communication, and 3) the convenience of portability. Based on this, a number of studies have sought to improve user acceptance and ultimately increase the usage of applications by applying the TAM. In a preliminary study, perceived usefulness and perceived ease of use are separated and set as external variables which affect the content of the application. These studies thus define the factors that are likely to influence the content of the application. If the relationship between the elements is positive, the external factor influences the content of the application, but if the relationship between the elements is negative, the external factor does not influence the content. In addition, they also provided a structural diagram of the TAM.

Table 1. External Variables Used in the TAM

Author (year)	Content	External Variables
Park (2012)	Examines the relationships between concepts related to a travel agency application and describes implications for the use of the application	Quality of Content, Faith of Application, Travel Company
Kim (2012)	Analyzes the motivation behind the use of mobile applications based on four external factors	Utility, Quality of Content, Entertainment, Price, Design
Lee (2014)	Proposes an evaluation model for BIM acceptance based on organizational culture	Personalization, Organization, Collaboration Environment
Shin (2016)	Analyzes factors affecting the continued use of mobile shopping applications among adults in their 20s and 30s.	Interaction, Information Offer, Personalization, Playfulness, Instant Connectivity

Park (2012) identified a relationship between positive and negative factors in applying the extended TAM to a travel agency's application. Kim (2012) reviewed commercial applications and employed five external factors (utility, content, entertainment, price, and design) in the TAM to investigate their relationship with perceived usefulness and ease of use. Lee (2014) defined external variables which affect organization culture or BIM acceptance and verified the hypothesis. Lastly, Shin (2016) analyzed the level of acceptance using the TAM for a shopping application.

The external variables identified from the literature review are presented in Table 1 and classified according to time to market, flexibility, and integration, which are factors that need to be considered when establishing the requirements for program development. According to Kim (2015), time to market enables users to accomplish very complex tasks in a short period of time. Flexibility is the ability of an application to work effectively regardless of the working environment, and integration means it can be used in conjunction with existing systems.

The external variables considered in the literature review can be divided into six types. Time to market is associated with external variables related to the convenience of providing information, such as utility, quality of content, and information offer. Flexibility is associated with external variables related to the connection with the environment, such as personalization and instant connectivity. Integration relates to variables related to the convenience of communication and information sharing, such as a collaborative environment and interaction. In addition, entertainment and playfulness are related to playability, design is related to convenience of use, and price is related to economic efficiency.

Therefore, the external variables that should be considered in the TAM model for the development of BIM application tools for portable devices are the convenience of providing information (time to market), the connection environment (flexibility), communication and sharing of information (integration), playability, convenience of application use, and economic efficiency. If the TAM can be verified by setting hypotheses related to perceived usefulness, perceived ease of use, attitude toward using, and behavioral intentional use, it is expected that BIM application tools for portable devices can be developed to reflect user acceptance.

3. Conclusions

With the development of ICT, the development of portable device-based technology has taken on increased importance, with the use of ICT also increasing in the construction industry. If BIM application tools for portable devices that manage building information from the PC environment are developed, the convenience and universality of technology use are expected to improve. However, although various portable device-based technologies have been developed, it is seldom the case that their functions are implemented based on a needs analysis of potential users.

Therefore, in this study, external variables for the TAM are identified based on a literature review in order to develop BIM applications for portable devices. This study analyzes past research that has used the TAM to develop portable device-based applications in other industries and examines the external variables used in those studies. Based on this, external variables that can be used to develop BIM application tools for portable devices are categorized into six types.

This study does not attempt to verify the hypothesized relationships using the TAM, but rather identifies external variables that can be used in the TAM. Therefore, in future research, external variables for the six categories should be specified based on the factors suggested in this study, and the hypotheses verified by establishing the relationships between the external factors. This study contributes to fundamental research regarding the development of application functions that reflect user requirements.

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