Automation in Construction 25 (2012) 82–93

Contents lists available at SciVerse ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Success model of project management information system in construction

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ARTICLE INFO

Article history:
Accepted 18 April 2012
Available online 25 May 2012

Keywords:
Project Management Information System (PMIS)
IS success model
Construction
Structural equation model

ABSTRACT

Among various IT solutions, the internet-based (or web-based) PMIS has been highlighted because of its strong advantages. While not sufficient to insure project success, using PMIS to manage projects has thus become a necessity. Establishing a success model of a specific information system is critical to understand the mechanism of IS success, the various dimensions of IS performance, and the factors and their causal relations in IS success. As one of the key IT applications, the project management information system (PMIS) has played a significant role in construction management processes. While not sufficient to insure project success, using PMIS to manage projects has thus become a necessity. However, research that attempts to establish or apply an IS success model have relatively recently begun to emerge and not many have been carried out as yet. Therefore, the main propose of this study is to develop and validate the ASP-PMIS success model based on the DeLone and McLean (2003) IS success model. A questionnaire instrument was remitted to experienced users (CMs and constructors), and 253 completed questionnaires were retrieved. Using AMOS 18.0, we used Structural Equation Modeling for hypothesis testing. The validated ASP-based PMIS success model can serve as a foundation for positioning and comparing PMIS success research, and can provide users with a useful framework for evaluating PMIS success.

1. Introduction

The architectural, engineering, and construction (AEC) industry is characterized by fragmentation which exists both within individual phases as well as across project phases [1]. Because of this fragmentation, participants from various organizations who are involved in a project phase or in different project phases are facing ineffectiveness and inefficiency in their coordination, collaboration and communication processes. As a tool to reduce the problems generated by this fragmentation, Information Technology (IT) is routinely and extensively used in the construction industry [2]. Powerful project management software has become a prerequisite to manage the projects more efficiently and effectively, and aid the project managers in their decision-making [3]. The advantage of an information system is that it helps to promote productivity by effectively processing and providing necessary information to an organization and supporting their efficient work performance.

The importance of information has been emphasized for enhancing communication, and the efficient management of construction information has been emerging as an element that determines the success of a project that involves many stakeholders [4]. Thus, in construction projects, various types of IS, such as construction management or business software, have been developed, applied, and widely used [5]. In the Korean construction industry, in particular, a project management information system (PMIS) is being extensively utilized due to its numerous advantages. It is very important to systematically assess the effects of the utilization of IS as well as other managerial resources on project management. Such assessment is essential for establishing and utilizing effective, efficient IS. Moreover, it is necessary to assess the success and performance of an established IS with appropriate criteria for continual improvements.

The research related IS assessment, which has been actively conducted, can be divided largely into research to assess quantitative performance and qualitative performance [6]. Nevertheless, in both types of research, it is as important to determine the factors affecting the success of IS utilization as it is to assess its performance. This is because the factors can be used to predict the performance or success of an IS or to define a mechanism for achieving the success of an IS. In this respect, IS success models are significant in relevant research fields for the following reasons. First, IS success models are used to provide a generalized framework that explains IS success, enabling researchers to select and define one dimension that is appropriate for a certain condition [7]. Second, based on proven IS success models, a systematic combination of individual criteria that correspond to the IS success category can facilitate the establishment of a comprehensive scale for measuring the success of an IS [8]. Third, IS success models can be used by researchers to explore the causal relationship between the success of an IS and its drivers and can be used as a mechanism by end-users to determine whether the expected performance of an IS has been achieved [9]. Fourth, numerous studies that

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doi:10.1016/j.autcon.2012.04.015

attempted to empirically verify IS success models firmly support the relationship of the criteria to success and help to ascertain the causal structure in models [7]. One of the most widely applied IS success models is the DeLone and McLean IS success model. DeLone and McLean proposed various views and variables of the success of an IS [10] and, since then, a significant amount of research in many fields has been conducted to verify, extend, and improve the model. In the construction field, research using IS success models has recently been carried out to examine a success model for enterprise resource planning (ERP) in construction [11,12], the utilization of electronic document management (EDM) [13], and the effect of a PMIS on project managers and project success [14]. Nonetheless, research of success models for ASP-based PMIS that reflect construction project stakeholders' opinions are scarce in Korea and, accordingly, any mechanism for the performance achievement or the success of ASP-based PMIS has yet to be defined.

The main purpose of this research is to develop and validate the ASP-based PMIS success model based on a revised version of the DeLone and McLean IS success model that is already widely applied [5]. This research is structured as follows. First, we review IS Success Models developed by other researchers and PMIS in construction and define PMIS success in construction. Second, based on a literature review, each measured item of the PMIS success model and a comprehensive set of hypotheses are proposed. Third, the methods and results of a survey are presented. Finally, theoretical and managerial implications and directions for future research are discussed.

PMIS in construction can be largely categorized into three types of information systems: those that are self-developed and used in construction firms; systems based on a widely distributed application service provider (ASP); and specialized systems used in specific capital projects [15]. The data used to test the research model were obtained from a sample of experienced users (CMs and constructors) of PMIS. To generalize the results, the respondents were spread across construction sites. Using AMOS 18.0, we used structural equation modeling (SEM) for hypothesis testing. A two-phased approach was used, based on Anderson and Gerbing [16]. First, the measurement model was estimated using confirmatory factor analysis (CFA) to test the overall fit of the model, as well as its validity and reliability. Second, the hypotheses were tested between constructs using the structural model.

Based on this analysis, this study will also discuss whether an existing IS success model can be effectively applied to ASP-based PMIS and will make suggestions for the development of an IS success model suitable for an ASP-based PMIS. The elements of success that are verified through the ASP-based PMIS success model suggested in this study can be used to assess systems and predict their success. Moreover, the implications of this research are expected to contribute to the development of a success model with higher explanatory power in the future.

2. Theoretical background

2.1. IS success model

The concept of information system (IS) success is widely accepted for the evaluation of information systems [17]. In management information systems (MIS) scholarship, a wide range of research has proposed IS success models [7,10,18–21]. These models postulate their own definitions of IS success and factors that affect the defined IS success; the models are theoretically grounded and empirically tested. Therefore, various studies have been carried out in which the success factors of the models are applied to the evaluation of IS success or performance.

After reviewing over 180 papers on IT investment assessment factors published in the 1970's and 1980's, DeLone and McLean [10] presented an IS Success Model with six factors related to the success of information systems: system quality, information quality, user satisfaction, system use, individual impact, and organizational impact. While the model integrates the comprehensive dependent variables used by IS researchers, it has received several criticisms. First, IS use in the DeLone and McLean model offers too many interpretations for it to be appropriately examined. IS use is also argued to play a problematic and controversial role in modeling system success. Second, because User Satisfaction represents the individual impacts of IS in an organizational setting, investigating the cause path from User Satisfaction to individual impacts is fruitless. Finally, and most importantly, the model does not explain clearly and fully the relationship between user satisfaction and individual/organizational impact [22]. The definition of constructs is as follows.

① System quality: measures of the information processing system itself
② Information quality: measures of information system output
③ (Information) use: recipient consumption of the output of an information system
④ User satisfaction: recipient response to the use of the output of an information system
⑤ Individual impact: the effect of information on the behavior of the recipient
⑥ Organizational impact: the effect of information on organizational performance(Fig. 1)

Seddon and Kiew [18] tested a modified version of the DeLone and McLean model [10], with the following three major differences: (a) use was replaced by usefulness, (b) a new variable, system importance, was added to help explain the variations in the users' perceptions of usefulness and user satisfaction, and (c) the simultaneous causality between Use and User Satisfaction was replaced by one-way causality, i.e. usefulness causes user satisfaction, and not vice versa. Their empirical results provided substantial support for the 'upstream' two thirds of the DeLone and McLean model [10]. Also, Seddon [19] presented an IS Success Model in which society impact as a net benefit of the information system is added (Fig. 2).

The IS success model of Pitt et al. [20] added Service Quality as a quality factor to the DeLone and McLean model [10]. Measurement items for assessing service quality consist of the modified SERVQUAL proposed by A. Parasuraman et al. [23]; validity was then tested (Fig. 3).

Myers et al. [21] proposed a success model by extending the model of DeLone and McLean [10] and Pitt et al. [20]. Their model differs from that of DeLone and McLean and Pitt et al. as follows: (a) the addition of service quality and (b) the addition of a workgroup to consider organization and external environment in terms of the contingency theory approach (Fig. 4).

Ten years later, DeLone and McLean [7] presented an updated model reflecting the criticisms by other researchers and the situation at the time. As the service concept was added to IT with the use of the Internet, they increased the number of information system success factors to seven, including service quality, and analyzed the interdependence and correlation of these seven factors (Fig. 5).

Drawing from previous research, many empirical studies supported the left-hand part of the DeLone and McLean model, which assumed that 'System Quality', 'Information Quality' and 'Service Quality' cause 'System Use' and 'User Satisfaction'. It has been shown that quality influences attitude and behavior in an IS context. However, many debates have arisen on the construct of information system success. The construct of information system success is varied according to the domain.

In the field of construction, researches that attempt to establish or apply an IS success model have relatively recently begun emerging and few have yet to be carried out. Studies of IS success models in the field of construction include the following. (a) Based on the DeLone and McLean IS Success Model and the technology acceptance model (TAM), Chung et al. [11,12] attempted to determine the elements of

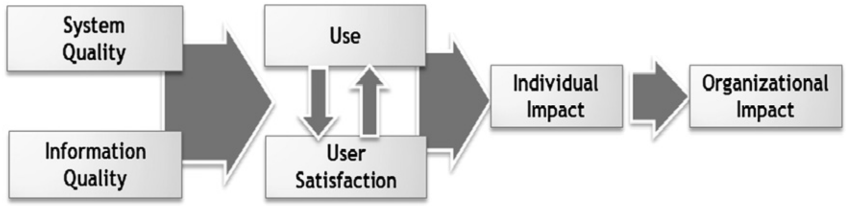

Fig. 1. DeLone and McLean IS success model [10].

the success or failure of the introduction of ERP systems that are widely utilized in construction enterprises with the purpose of contributing to assessing, planning, and conducting a project for introducing and establishing an ERP in an enterprise. In the research, the success factors of the ERP system are divided into two categories; the first category is user-related variables, including output, job relevance, image, result demonstrability, compatibility, and system reliability. The second category is project-related variables, including internal support, function, and consultant support. It can be said that this research has a high level of completion in that it suggested a success model for construction ERP systems through extensive data collection and empirical analysis. Nevertheless, the success model suggested has limitations in its application to other types of IS because it was verified by focusing on ERP systems. (b) Hjelt and Bj k [13] analyzed factors related to end-users' attitudes toward EDM systems that are used for large-scale construction projects. The research conducted a survey to draw factors that affect acceptance of an EDM system to a construction project. Based on these factors, the DeLone and McLean IS success model and the TAM, a model was suggested that explains the mechanism in which an end-user accepts an EDM system in a construction project. (c) Similar to the studies above, Raymond and Bergeron [14] suggest a success model for a PMIS based on the IS success model and the TAM. According to this research, the fundamental factors that affect the PMIS success are PMIS quality and PMIS information quality. For the measurement of PMIS quality, eight items were used: accessibility, response time, flexibility, ease of use, querying ease, learning ease, systems integration, and multi-project capability. For the measurement of PMIS information quality, six items were used: availability, relevance, reliability, precision, comprehensiveness, and security. However, as the authors clarified, the greatest flaw in this study is that the model was verified by a very small number (39) of samples.

Most relevant studies have developed an IS success model based on the DeLone and McLean IS success model or the TAM. This indicates that most IS success models have been based on either of the two models. Thus, this study intends to suggest a success model for ASP-PMIS based on the models or their components.

2.2. Project management information system in construction

Among various IT solutions, the internet-based (or web-based) PMIS has been highlighted because of its strong advantages such as low cost compared with traditional communication methods, location-free access, speedy and reliable data transfer and storage, and efficient information sharing among parties [24–26]. The Engineering New Record (ENR) has also reported the increased use of web-based PMIS [27]. The situation is very similar in the Korean construction industry. Web-based PMIS has become one of the most widely used tools that supports and enhances the collaboration and communication between construction project participants. The reason for the swift adoption of web-based PMIS in the Korean construction industry closely relates not only to the above-mentioned advantages, but also to the well-established internet infrastructure and users' familiarity with web-based computing environment. Besides these technical reasons, the construction management guidebook [28] that specifies the use of PMIS by construction managers hired by government or government agencies for efficient information management has strongly facilitated the adoption of web-based PMIS in the Korean construction industry.

For efficient work performance between the project related participants (client, contractor, and architect), PMIS supports three basic functions [29]: (a) communication — it supports work efficiency through smooth communication by delivering related knowledge and information promptly between participants using an internal or external network, (b) collaboration — it supports an active cooperative management system among related participants for practical project management, and (c) community — it supports the accumulation of related information and data through information sharing.

Therefore, PMIS provides the framework for collecting, organizing, storing, and processing project information. It provides the basis for assessing the status of the project with respect to time, cost, and performance goals and objectives. It also provides a type of business intelligence about how the project contributes to the organization's strategy and success. It enhances the improvement of the project success by 75%. Hence, the quality and use of PMIS are highly essential [14].

3. The proposed PMIS success model

3.1. Overview of proposed model

As explained in chapter 2, PMIS supports project management for project success. Using PMIS to manage projects, while not sufficient to

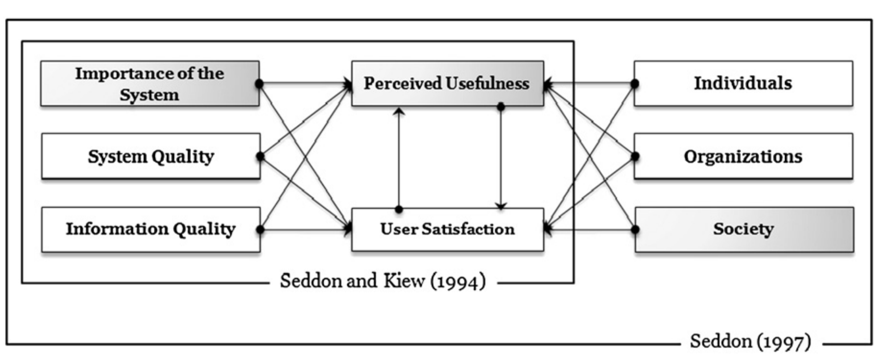

Fig. 2. Seddon and Kiew success model [18] and Seddon success model [19].

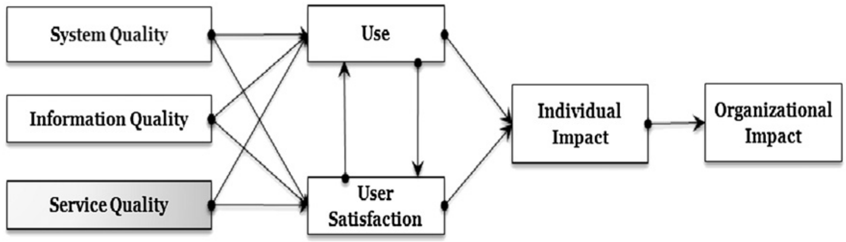

Fig. 3. Pitt, Watson and Kavan Success Model [20].

insure project success, has thus become a necessity. That is, PMIS is necessary to efficiently and effectively manage these projects. Therefore, a successful PMIS should have an impact on efficient project management in terms of the job performance of project managers (such as improving communication among stakeholders, speed and accuracy). Also, a successful PMIS should have an impact on effective project management in terms of project performance (such as budget, schedule, and quality).

Our objective is thus to improve our understanding of the impacts of PMIS quality on effective and efficient construction management based on a revised version of the DeLone and McLean IS success model that is already widely applied. In this research, PMIS quality is suggested as a dependable variable, which influences users' intention or satisfaction with respect to the system, rather than the aspect of PMIS user. That is, the quality of PMIS, one of the means for providing construction management, will positively affect user satisfaction and intention of PMIS use. User satisfaction, which is individual satisfaction, will positively affect Intention to use PMIS. Organizational communication is improved by organizationally expanding PMIS usage. Ultimately, this will positively impact on efficient and effective construction management.

The amendments include the following. (a) The addition of service quality. ASP-based PMIS is a type of outsourcing service for information systems which provides various services for products, hardware/software installation and maintenance. Thus, service quality is an important success factor in this survey and must be assessed. (b) The impacts of efficient construction management and effective construction management are suggested as the final dependent variables. As the 'impacts' of IS have evolved beyond the immediate user, researchers have suggested additional IS impact measures, such as work group impacts [30,31], interorganizational and industry impacts [32,33], consumer impacts [34,35], and social impacts [19]. The choice of where the impacts should be measured will depend on the system or systems being evaluated and their purposes. ASP-based PMIS leads to effective project performance and efficient job performance of project managers by the sharing of various types of information. Therefore, in this research, the impacts of efficient construction management and effective construction management are the impacts of IS. (c) Detailed assessment items of constructs were corrected within the context of ASP-based PMIS in construction. Using this prior study on quality assessment and a successful information system model, we collected detailed assessment items to be used in this study. Based on this, items with similar meanings or for specific information systems were deleted. Items were then corrected to assess the construction of PMIS quality by reflecting the construction industry and ASP based IS.

3.2. PMIS quality

In previous research on success measurement of the IS, to continually obtain the expected effect of PMIS usage, efforts to improve user satisfaction is required by improving the existing system through systematic assessment and management of PMIS quality. Also in this research, improving the quality of information system is suggested as a prerequisite for a successful information system.

In this research, a total of twenty-five quality factors of ASP-based PMIS were initially selected from the above mentioned IS success models and other various researches [7,10,22,23,36–42]. The factors were classified into three categories (system quality, information quality, and service quality), which were originally proposed by DeLone and McLean's IS success model [7]. Then, a questionnaire was developed to collect the users' opinions on the current ASP–PMIS. The content validity of the twenty-five items in the questionnaire was tested through face-to-face interviews with three experts from the three respective ASP-based PMIS providers. The experts' average experience in ASP-based PMIS development was eight years. The experts were also asked to review the redundancy and adequacy of the quality factors of ASP-based PMIS in the questionnaire. After the interview, the number of factors was reduced to twenty-three, consisting of seven for system quality, six for information quality, and ten for service quality.

The next step involved testing the construct validity using an exploratory factor analysis (EFA), which is generally used to identify a relatively small number of factor groups that can be used to represent relationships among sets of many inter-related variables. In the EFA, a total of 253 users' responses that were collected by the developed questionnaire were used.

In general, two main issues need to be considered in determining whether a data set is suitable for factor analysis: the sample size and the strength of the relationship among the variables [43]. In terms of a sample size, different researchers have suggested different sample sizes. Hair et al. [44] argued that an appropriate sample size should be at least 4–5 times the number of variables; however, Nunnalyy [45] suggested at least 10 times the number of variables. In this study, the sample size was larger than 10 times the number of variables, which

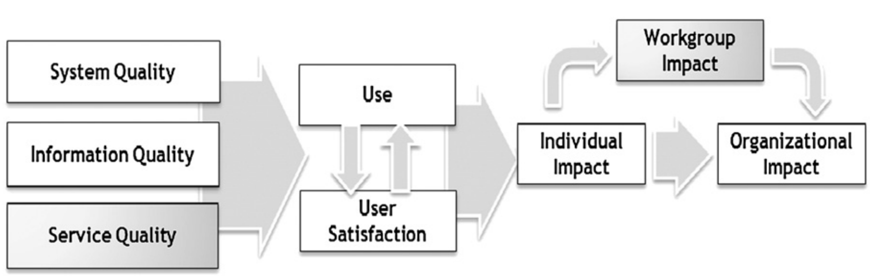

Fig. 4. Myers, Kappelman and Prybuton success model [21].

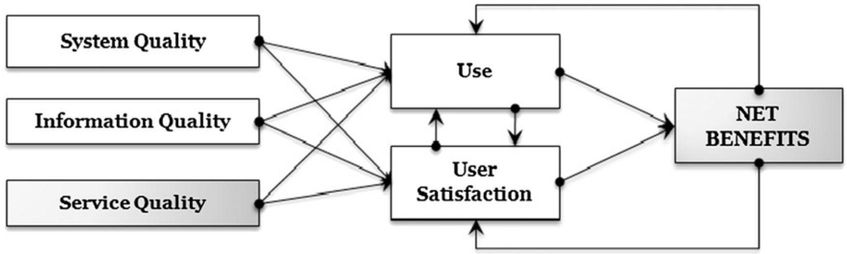

Fig. 5. DeLone and McLean IS success model [7].

was sufficient for factor analysis. On the other hand, in terms of the strength of the relationships among the variables, the kaiser myer olkin (KMO) test [46] and the Bartlett's test of sphericity [47] were recommended. The KMO index is a measure of sampling adequacy, and the sphericity statistic tests whether the correlations among variables are too low for the factor model to be appropriate. For the KMO index of sampling adequacy, a value above 0.6 is required for good factor analysis, and our value of 0.95 was satisfactory. For Bartlett's test of sphericity, a significant value of less than 0.05 ($p<0.05$) is required and ours was satisfactory. Therefore, the results of these tests confirmed that the data were appropriate for factor analysis.

The criteria used in the EFA were 'eigenvalues greater than 1' and 'factor loadings greater than 0.5' [48–50]. Eigenvalues determine the number of factors. The sum of the squared loadings of the variables on a factor is known as the eigenvalue of the factor. Dividing the eigenvalue by the number of variables gives the proportion of variance explained by the factor. The higher the eigenvalue, the higher the proportion of variance explained by the factor; so it is possible to set a criterion eigenvalue for the acceptance of a factor as being important enough to consider. By convention, the usual criterion value is 1. In this research, we used principal component analysis with varimax rotation as the method for data analysis. The factor analysis identified three factor groups: system quality with five factors, information quality with ten factors, and service quality with eight factors.

Finally, reliability of the factors was tested using a Cronbach's coefficient alpha value. The Cronbach's α value that is considered to be acceptable is 0.6 [45]. The test result showed that the Cronbach's α ranged from 0.835 to 0.941 and this confirmed that the measures used in the assessment were statistically reliable. The process of selecting quality factors of ASP-PMIS is explained in more detail in the authors' previous study [51], and the resulting quality factors are summarized in Table 1.

3.2.1. System quality

System quality represents the quality of the information system processing itself, which includes software and data components. System quality also measures the extent to which the system is technically sound. Seddon [19] notes that system quality is concerned with whether there are bugs in the system, the consistency of user interface, ease of use, quality of documentation, and sometimes, quality and maintainability of the program code. DeLone and McLean [7] report that System quality is measured by attributes such as ease of use, functionality, reliability, data quality, flexibility, and integration. Sedera and Gable [52] developed and validated a comprehensive instrument for system quality which resulted in ten attributes: ease of use, ease of learning, user requirements, system features, system accuracy, flexibility, sophistication, integration, integration, and customization. Edward and Bernroider [53] measured system quality through three attributes: flexibility, interoperability, and functionality. Liu and Arnett [40] measured system quality through six attributes: rapid access, quick error recovery, security, correct operation, coordination, and balanced payment.

Drawing from these previous researches, we group the attributes for system quality into two broad categories: connectivity and usability. The connectivity dimension reflects ASP-based PMIS for compatibility with (a) other software and (b) the IT tool. The usability dimension denotes (a) ease of use, (b) accessibility, and (c) stability in use.

Table 1
Assessment items and factors for ASP-based PMIS quality.

Factors		Assessment items
System Quality (5)	Connectivity	PMIS should be compatible with other soft wares (such as Excel, P3, CAD)
		PMIS should connect to other IT tools (such as PDA, RFID, USN)
	Usability	Data input/output functions should be operated easily (e.g., up/download, printing)
		Access to system should be not difficult
		System should maintain the stable state
Information Quality (10)	Format	System functions and configuration should be related to required information
		System screen configuration or document formats should be suitable for information use
	Currency	Search of information should be easy
		PMIS should offer information to users on real time
	Accuracy	Information in system should be reliable
		Information in system could be used without correction
		Information in system should be sufficient
	Relevance	Information in system should be related to user's task
		Information in system should be related to project characteristics.
		Options for information usage should be various depending on the user's task
Service Quality (8)	Responsiveness	Reaction of PMIS service provider should be quick in the situation
		Technical support of PMIS service provider for maintenance and repair should be quick.
	Follow up Service	Education for PMIS users should be provided adequately
		User's manual and advice should be provided adequately during use
	Assurance	PMIS service provider should possess knowledge of construction field
		PMIS service provider should be faithful
	Reliability	User should feel safe regarding data security
		User should trust capability of PMIS service provider

3.2.2. Information quality

Information systems are created to provide useful decision making information to individuals and groups by storing, maintaining, processing and managing information resources. Their values are realized when the information provided is applied to operations. Swanson [54] claimed that information quality is a critical factor that determines the success of information systems. Information quality refers to the quality of outputs the information system produces [10], which can be in the form of reports or online screens. Ballou and Pazer [42] define four dimensions of information quality: accuracy, completeness, consistency and timeliness. There are several dimensions to data quality. Nelson et al. [55] have used the constructs of accuracy, completeness, currency, and format for information quality; the additional construct used by these authors' format is related to the presentation layout of information outputs.

Accuracy is most commonly defined as correctness in the mapping of stored information to the appropriate state in the real world that the information represents [7,55–59]. Completeness means that all values for a certain variable are recorded. It focuses on whether all values for all variables are recorded and retained [55–59]. Consistency refers to when the representation of the data value is the same in all cases [42–56]. Currency refers to the degree to which information is up to date, or the degree to which the information precisely reflects the current state of the world that it represents [7,60,61]. Timeliness implies that the recorded value is not out of date. Data must be available in time to influence the decision and, therefore, can vary based upon the decision-maker and circumstance; a strategic planner may use information that is several years old, but a production manager must have recent data [7,56,59]. Format is tied to the notion of representational quality [55,61]. Format refers to the degree to which information is presented in a manner that is understandable and interpretable to the user, and thus aids in the completion of a task. Data relevance refers to the applicability of data in a particular issue by a particular user. Relevant data can be used directly in solving a business problem [42,62].

We arrive at four broad categories for information quality: format, currency, accuracy and relevance. Format measures the degree to which (a) system functions and configuration are related to required information and (b) system screen configuration and document formats are suitable for information use. Currency measures (a) how easy it is to search information and (b) PMIS offers information to users in real time. Accuracy measures the degree to which (a) information is reliable and (b) sufficient and (c) the degree of using the information without correction. Relevance measures the degree to which (a) information in a system is related to a user's task and (b) project characteristics and (c) the degree of various options depending on the user's task.

3.2.3. Service quality

ASP-PMIS is a type of outsourcing service for information systems and provides various services for products, hardware/software installation and maintenance. Thus, we believe that ‘service quality,’ properly measured, deserves to be added to ‘system quality’ and ‘information quality’ as components of IS success.

Pitt et al. [20] observed that commonly used measures of IS effectiveness focus on the products rather than the services of the IS function. Thus, there is a danger that IS researchers will incorrectly measure IS effectiveness if they do not include a measure of IS service quality in their assessment package. Other researchers have agreed with this, citing the need for a service quality measure to be a part of IS success [7,21,63,64]. Researchers who have argued that service quality be added to the success model have applied and tested the 22-item SERVQUAL measurement instrument from marketing to an IS context [20,63]. This instrument uses the dimensions of tangibles, reliability, responsiveness, assurance, and empathy to measure service quality. Liu and Arnett [40] identified service quality as an important measure of website success. In their empirical study, service quality was measured as quick responsiveness, assurance, empathy, and following-up service. DeLone and McLean [7] define service quality as the overall support delivered by the service provider, and it applies regardless of whether this support is delivered by the IS department, a new organizational unit, or outsourced to an Internet service provider. They measured service quality through three attributes: assurance, empathy, and responsiveness.

We arrive at four broad categories for information quality: responsiveness, follow up service, assurance, and reliability. Responsiveness measures (a) quickness of reaction to change in the situation and (b) quickness of technical support for maintenance and repair. Follow up service measures the degree to which (a) user's education, (b) manuals and advice are provided to users during use. Assurance measures the degree to which (a) the PMIS service provider possesses knowledge of the construction field and (b) whether the PMIS service provider is faithful. Reliability is the degree of trust of (a) safety regarding data security and (b) capability of the PMIS service provider.

3.3. User satisfaction and intention of PMIS use

A great deal of research on customer satisfaction has recognized that it was a superordinate concept of product quality and that it mediated causal relationships between product quality and behavior intention. This explains that improved product quality increases customer satisfaction and leads to repurchase and word-of-mouth intention, thereby regulating switching costs and enhancing corporate performance [65,66]. Also, according to the previous research related IS success model, user satisfaction is a critical factor as a variable that mediates the quality of an information system and the success of an information system. Based on the previous research mentioned above, this research assumed that the quality of PMIS will positively affect user satisfaction and intention of PMIS use. Further, user satisfaction is not restricted to individual satisfaction but positively affects the intention of PMIS use, through which PMIS use is expanded and sharing of information is facilitated within an organization; user satisfaction acts as a premise for efficient and effective construction management.

3.3.1. User satisfaction

User satisfaction is a factor that mediates improved levels of services or system performance felt by users and a successful information system. In other words, user satisfaction is one of most widely used components in the IS success model as a cause variable influencing the success of an information system and at the same time an effect variable of information system quality. Ives and Olson [67] stated that user satisfaction was the degree of meeting the information needs of users. Measurement of user satisfaction is usually composed of experiencing information system goods or services and then evaluating the results.

DeLone and McLean showed that user satisfaction is one of the most widely used success measures of an information system's success. Three questions were developed to assess user satisfaction of a respondent's PMIS. Items included questions about satisfaction with PMIS quality and offered the cost of PMIS used by the respondent as well as the degree of use of information provided by PMIS.

3.3.2. Intention of PMIS use

One of the major purposes of PMIS is the smooth sharing of information among project stakeholders and therefore, when the use of PMIS is expanded among them, and not restricted to individual users, the effects become greater. In other words, positive effects of improved quality of PMIS should lead to intention of use, not limited to satisfaction with its use, thereby expanding its use; then, smooth information sharing and systematic information management would be enabled, thereby enhancing efficient and effective construction management. Behavioral intention is a measure of the strength of one's intention to perform a specified behavior [68]. Many researches expect that behavioral intention have a significant positive influence on technology acceptance.

This research defined intention of PMIS use as the efforts and attitudes to expand its use. In other words, it is an intention of continuously reusing or recommending to others the information system based on previous experiences. Therefore, this research utilized intention to reuse and recommendation as items to evaluate intention of PMIS use. The detailed assessment items for user satisfaction and intention of PMIS use are as follows (Table 2).

3.4. PMIS success

PMIS is necessary to efficiently and effectively manage projects. Thus, a successful PMIS should have an impact on efficient project management and an impact on effective project management. “Efficient” is defined as working without waste or using a minimum of time, effort and expense. Project managers can be very efficient in their tasks but still not attain their desired goal because they are not carrying out the right tasks. ‘Effective’ now becomes important. ‘Effective’ means ‘having the desired result’. Based on the above concept, in our context, the impact of efficient construction management is perceived of in terms of job performance of project managers (such as improving communication among stakeholders, speed and accuracy). Also, the impact of effective project management is perceived of in terms of project performance (such as budget, schedule, and quality).

3.4.1. Impact of effective construction management

Effective construction management is related to achieving performance as project success factors. In the literature review of project success (Table 3), the critical success factors of the project are defined as cost, time and quality. In addition, because issues of safety and environment have recently been confronted in construction, safety and environment have emerged as the key success factors.

In this research, effective project management is used to assess whether the project success factor, the management area supported by PMIS, is effectively accomplished.

3.4.2. Impact of efficient construction management

If effective construction management is related to the factor of project success, efficient construction management is related to the factor affecting project success. Factors affecting project success are classified as uncontrollable factors such as the type of project and type of contract because these are already fixed, while controllable factors include project managers' competency and support system. In the literature review of factors affecting project success (Table 4), relatively more research has been carried out on the controllable factors of competency of project managers and improvement of support systems.

In this research, efficient construction management focuses on the competency of project managers as PMIS users.

Therefore, the detailed assessment items for the impacts of effective and efficient construction management are as follows (Table 5).

Table 2
Assessment items for user satisfaction and intention of PMIS use.

Factors	Assessment items
Intention of PMIS use	I have intention to recommend to others. I have intention to reuse in future.
User Satisfaction	I satisfied overall system quality, information quality, and service quality. I satisfied with the offer price of system. I actively utilized information provided by system

Table 3
Factors of project success.

Definition	Authors
A project is generally considered to be successfully implemented if it - Comes in on-schedule (time criterion) - Comes in on-budget (monetary criterion) - Achieves basically all the goals originally set for it (effectiveness criterion) - Is accepted and used by the clients for whom the project is intended (client satisfaction criterion)	Pinto and Slevin [69]
Project success is usually defined as meeting time, cost, quality objectives and satisfying project stakeholders.	Baccarini [70]
Result much better than expected or normally observed in terms of cost, schedule, quality, safety, and participant satisfaction.	Ashley et al. [71]
Project success is measured against the overall objectives of the project	Anton [72]

3.5. Proposed model and research hypotheses

We proposed the research model for empirical analysis on the impacts of PMIS on effective and efficient construction management based on the previous literature review of the related IS success model. This is shown in Fig. 6. The proposed research model included 36 observed indicators describing 7 latent constructs (assessment items and factors introduced in Chapter 3): system quality, information quality, service quality, intention of PMIS use, user satisfaction, impact of efficient construction management and impact of effective construction management.

The quality of PMIS, one of means for providing construction management, will positively affect user satisfaction and intention of PMIS use. User satisfaction, which is individual satisfaction, will positively affect intention of PMIS use. Then PMIS usage organizationally expanded. By improving organizational communication, the efficiency of construction managers and effectiveness of construction management is improved. The hypotheses are established based on the proposed research model. This is shown in Table 6. The basis of the established hypotheses is presented in Chapter 3.

Using AMOS 18.0, we used Structural Equation Modeling for hypotheses testing. A two-phased approach was used, based on Anderson and Gerbing [16]. First, the measurement model was estimated using CFA to test the overall fit of the model, as well as its validity and reliability. Second, the hypotheses were tested between constructs using the structural model.

4. Model validation

4.1. Data collection

This case study aimed to propose a success model of ASP-based PMIS which is widely used in the Korean construction industry. Our

Table 4
Factors affecting project success.

Authors	Manager competency	Support system	Type of project	Type of contract	Object/ attitude
Belassi and Tukel [73]	○	○	○		
Chua et al.[74]	○	○	○		○
Chan et al. [75]	○	○	○	○	○
Ling and Liu [76]		○	○	○	○
Fortune and White [77]	○	○	○		
Yu et al. [78]	○	○			
Khang and Moe [79]	○	○		○	
Lam et al. [80]	○	○			
Muhammad et al. [81]	○	○	○		○
Lee et al. [82]	○	○			○
Hyeon and Jeo [83]	○	○			
Yu et al. [84]		○	○		

Table 5
Assessment items and factors for PMIS success.

Factors	Assessment items
Impact of Effective Construction Management	Time management is effectively conducted.
	Cost management is effectively conducted.
	Quality management is effectively conducted.
	Safety management is effectively conducted.
	Environmental management is effectively conducted.
Impact of Efficient Construction Management	Processing speed is improved (reduction of repetitive activity)
	Processing accuracy is improved (reduction of error)
	Communication among stakeholders is improved

research used the selected quality factors (twenty three factors) and Structural Equation Model. The data used for quality assessment were obtained from a sample of experienced ASP-based PMIS users among construction managers and contractors. This is because the major users of ASP-based PMIS in Korean domestic construction projects are generally construction managers and contractors. The questionnaire was sent by e-mail through the project directors of each organization. The survey was conducted between May 10 and August 9, 2010, and a total of 253 responses were received. A total of the 253 responses were valid and used for the analysis. Among the 253 respondents, 140 were from construction management organizations and 113 were from contractor organizations. Also, the responses were collected from a total of thirty-five projects, which consist of sixteen public projects and nineteen private projects. Furthermore, each item was measured on a 7-point Likert scale, with anchors ranging from 'strongly disagree' to 'strongly agree'. The descriptive statistics relating to the respondents' characteristics are shown in Table 7.

4.2. Measurement model

Common model fit measures were used to assess the model's overall goodness of fit: the ratio of X^2 to degree of freedom (df), goodness of fit index (GIF), adjusted goodness of fit index (AGIF), normalized fit index (NFI), comparative fit index (CFI), root mean square residual (RMSR), and root mean square error of approximation (RMSEA) [85]. As shown in Table 8, all the model-fit indices refer to their respective common acceptance levels suggested by previous research [86–88].

In Table 8, the model-fit indices of the proposed model and the acceptance level are compared. More than half the model-fit indices meet the acceptance level. Also, RMR, GFI, AGFI, and NFI, which did not meet the acceptance level, are close to the acceptance level. Thus we demonstrate that the measurement model exhibited a fairly good fit with the data collected.

To validate our measurement model, we undertook validity assessments of convergent and discriminant validity. Convergent validity can also be evaluated by examining the factor loading, the composite reliability of measures and the average variance extracted (AVE) by measures from the results of CFA.

Table 6
Research hypotheses.

Hypotheses		Definition
H1	a	System Quality will positively affect User Satisfaction
	b	System Quality will positively affect Intention of PMIS Use
H2	a	Information Quality will positively affect User Satisfaction
	b	Information Quality will positively affect Intention of PMIS Use
H3	a	Service Quality will positively affect User Satisfaction
	b	Service Quality will positively affect Intention of PMIS Use
H4		User Satisfaction in the PMIS will positively affect Intention of PMIS Use
H5	a	User Satisfaction will positively affect Impact of efficient construction management
	b	User Satisfaction will positively affect Impact of effective construction management
H6	a	Intention of PMIS Use will positively affect Impact of efficient construction management
	b	Intention of PMIS Use will positively affect Impact of effective construction management

Following the recommendation by Hair et al. [44], the factor loadings greater than 0.5 were considered to be very significant. The composite reliability for all the factors in the measurement model was above 0.6 [89] and the AVEs were all above the recommended 0.5 [44], which meant that more than one-half of the variances observed in the items were accounted for by their hypothesized factors. To examine discriminant validity, we compared the shared variances between factors with the average variance extracted of the individual factors [89]. The AVEs (see Table 9) should be greater than the square of the correlations (see Table 10) among the constructs [90]. That is, the amount of variance shared between a latent variable and its block of indicators should be greater than the shared variance between the latent variables.

As shown in Table 10, the factor loading of all factors is higher than 0.5 (recommended). The composite reliability is also higher than 0.6 (recommended). However, the AVE of system quality is 0.497, which did not quite meet the criterion. Also, the discriminant validity test (see Table 11) between 'information quality' and 'system quality' was not satisfied. However, not only is the result of EFA significant [51], but 'system quality' also consists of detailed items verified by professionals. Thus, in this paper, the system quality is not deleted.

4.3. Structural model

We used a similar set of fit indices to examine the structural model (see Table 9). A comparison of all fit indices with their corresponding recommended values provided evidence of a good model fit ($x^2 = 1538.259$, with df = 580, RMR = 0.108, GFI = 0.831, AGFI = 0.778, PGFI = 0.633, NFI = 0.887, TLI = 0.91, CFI = 0.925, and RMSEA = 0.095) Given an adequate measurement model, the hypotheses can be tested by examining the structural model.

Fig. 7 shows the standardized path coefficients, their significance for the structural model, and the squared multiple correlations (R^2)

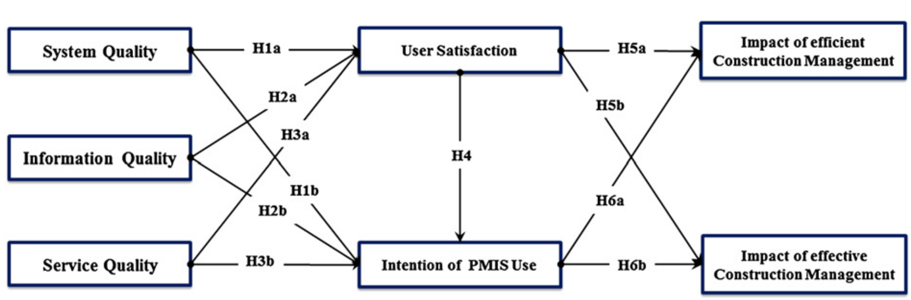

Fig. 6. Research model.

Table 7
Characteristics of the respondents (N = 253).

Measure		Frequency	%
Project type	Public project	113	44.7%
	Private project	140	55.3%
User type	Construction managers	140	55.3%
	Contractors	113	44.7%
Experience in construction	Less than 2 years	42	16.60%
	3–5 years	41	16.21%
	5–10 years	53	20.95%
	10–15 years	27	10.67%
	More than 15 years	90	35.57%
Respondents' average PMIS use		4.69 (hours per day)	

for an endogenous construct. The standardized path coefficient indicates the strengths of the relationships between the independent and dependent variables. The R^2 value represents the amount of variance explained by independent variables.

As expected, hypotheses H2a and H2b were supported ($\gamma = 0.332$, $\gamma = 0.159$, respectively). These implied that increased 'information quality' would be associated with increased intention of PMIS use and user satisfaction. For service quality, hypothesis H3a was supported and hypothesis H3b was rejected ($\gamma = 0.347$, $\gamma = -0.015$, respectively). The influence of service quality on intention of PMIS use was ($p < 0.05$) and had no impact on user satisfaction. However, system quality had no impact on intention of PMIS use and user satisfaction. Thus, H1a and H1b were rejected ($\gamma = 0.112$, $\gamma = 0.073$, respectively). Also, user satisfaction had a significant effect on intention of PMIS use ($p < 0.01$), and H4 was supported ($\beta = 0.586$).

We found that information and service quality had a significantly positive effect on user satisfaction. Altogether, they accounted for 53.3% of the variance; information quality contributed more to user satisfaction than service quality. Also, 55.7% of the variance in intention of PMIS use was explained by information quality and user satisfaction.

User satisfaction appeared to be a significant determinant of efficient/effective construction management. H5a and H5b were supported ($\beta = 0.559$, $\beta = 0.463$, respectively). Also, intention of PMIS use had a significant effect on both efficient construction management and effective construction management. H6a and H6b were supported ($\beta = 0.279$, $\beta = 0.361$, respectively). Hypotheses H5a, H5b, H6a and H6b indicated that intention of PMIS use and user satisfaction had a significantly positive effect on efficient/effective construction management. It could be suggested that a higher level of intention of PMIS use and user satisfaction would lead to a higher level of efficiency/effectiveness of construction management. H5a and H6a together explained 61.8% of the variance in efficient construction management. H5b and H6b together explained 52.8% of the variance in effective construction management. Among the three quality-related constructs, information quality had the strongest total effect on efficient/effective construction management. In addition, among the five constructs, user satisfaction had the strongest total effect.

Table 8
Fit indices for research model.

Fit indices	Recommended value	Measurement model	Structural model
x2/df	≤3.0	2.661	2.652
RMR	≤0.1	0.101	0.108
GFI	≥0.9	0.831	0.831
AGFI	≥0.8	0.768	0.778
PGFI	≥0.5	0.605	0.633
NFI	≥0.9	0.897	0.896
TLI	≥0.9	0.906	0.91
CFI	≥0.9	0.925	0.925
RMSEA	≤1.0	0.098	0.095

[86–88].

Table 9
Result of CFA.

Latent constructs	Observed indicators	Factor loading	t-value	Composite reliability	AVE
System quality	SyQ 1	0.527	[a]	0.679	0.497
	SyQ 2	0.579	7.020		
	SyQ 3	0.821	8.522		
	SyQ 4	0.717	8.249		
	SyQ-5	0.781	8.326		
Information quality	InQ 1	0.631	[a]	0.833	0.716
	InQ 2	0.808	10.790		
	InQ 3	0.719	9.869		
	InQ 4	0.756	10.263		
	InQ 5	0.779	10.492		
	InQ 6	0.804	10.753		
	InQ 7	0.812	10.827		
	InQ 8	0.752	10.219		
	InQ 9	0.804	10.751		
	InQ 10	0.733	10.02		
Service quality	SeQ 1	0.755	[a]	0.837	0.631
	SeQ 2	0.758	12.480		
	SeQ 3	0.727	11.903		
	SeQ 4	0.748	12.291		
	SeQ 5	0.797	13.222		
	SeQ 6	0.734	12.044		
	SeQ 7	0.806	13.410		
	SeQ 8	0.842	14.099		
User satisfaction	US 1	0.896	[a]	0.796	0.567
	US 2	0.780	14.347		
	US 3	0.824	17.645		
Intention of PMIS use	U 1	0.946	[a]	0.876	0.780
	U 2	0.953	27.473		
Impact of Efficient Construction Management	EFFI 1	0.874	[a]	0.800	0.573
	EFFI 2	0.944	21.545		
	EFFI 3	0.787	15.781		
Impact of Effective Construction Management	EFFE 1	0.844	[a]	0.907	0.663
	EFFE 2	0.803	28.851		
	EFFE 3	0.929	28.585		
	EFFE 4	0.931	18.808		
	EFFE 5	0.943	21.204		

SyQ: System Quality, InQ: Information Quality, SeQ: Service Quality, US: User Satisfaction, U: Intention of PMIS Use, EFFI: Impact of efficient construction management, EFFE: Impact of effective construction management
AVE: Average Variance Extracted.
[a] t value for these parameters were not available because they were fixed for scaling purpose.

Table 10
Correlation matrix of factors.

	SyQ	InQ	SeQ	U	US	EFFI	EFFE
SyQ	1	0.800***	0.668***	0.548***	0.610***	0.493***	0.521***
InQ		1	0.775***	0.611***	0.691***	0.593***	0.559***
SeQ			1	0.555***	0.679***	0.584***	0.596***
US				1	0.731***	0.687***	0.654***
U					1	0.763***	0.694***
EFFI						1	0.695***
EFFE							1

*** $p < 0.01$.

The direct, indirect and total effects of system quality, information quality, service quality, intention of PMIS use, user satisfaction, efficient construction management, and effective construction management are summarized in Table 12.

5. Conclusion

The ASP-based PMIS is recognized as an essential supporting tool in construction management for successful project performance. To

Table 11
Result of discriminant validity test.

Observed indicators		r^2	AVE		Discriminant validity
System quality	InQ	0.640	0.497	0.716	X
	SeQ	0.446		0.632	O
	U	0.300		0.781	O
	US	0.372		0.567	O
	EFFI	0.243		0.573	O
	EFFE	0.272		0.664	O
Information quality	SeQ	0.601	0.716	0.632	O
	U	0.373		0.781	O
	US	0.477		0.567	O
	EFFI	0.351		0.573	O
	EFFE	0.312		0.664	O
Service quality	U	0.308	0.632	0.781	O
	US	0.461		0.567	O
	EFFI	0.341		0.573	O
	EFFE	0.355		0.664	O
User satisfaction	U	0.534	0.567	0.781	O
	EFFI	0.472		0.573	O
	EFFE	0.428		0.664	O
Intention of PMIS use	EFFI	0.582	0.781	0.573	O
	EFFE	0.482		0.664	O
Impact of Efficient Construction Management	EFFE	0.483	0.573	0.664	O

obtain expected effectiveness using ASP-based PMIS, efforts to increase user satisfaction by improving existing systems through the process of understanding user demands through periodical evaluations are needed. Therefore, this study develops and validates ASP-based PMIS success model in construction. The proposed success model consists of seven factors including system quality, information quality, service quality, intention of PMIS use, user satisfaction, impact of efficient construction management and impact of effective construction management. In this model, efficient and effective construction management is used to measure PMIS success.

In this research, several important implications for PMIS success are as follows.

5.1. The good model fit of research model

"The impact of efficient construction management" and "the impact of effective construction management" constitute more than 50% of the variance. This means that the configuration of constructors is correct. According to the proposed model, the impact of efficient construction management and the impact of effective construction management are considered to be a closer measure for PMIS success than the other five constructs. We also obtain evidence that there are strong connections between the five success constructs, supporting the hypothesized relationships, except the relationships between "system quality" and other constructs. That is, information and service quality of PMIS, one of the means for supporting construction management, will positively affect "intention of PMIS use" and "user satisfaction". User satisfaction, which is individual satisfaction, will positively affect intention of PMIS use. Organizational communication is improved by organizationally expanding PMIS usage. Ultimately, this will positively affect efficient and effective construction management. Therefore, in order to increase efficient and effective construction management, the developer of PMIS needs to appropriately develop and manage information systems with good information quality and service quality, which in turn will influence PMIS usage behavior and satisfaction.

5.2. The relationship of user satisfaction and PMIS success

User satisfaction has the strongest total effect on efficient and effective construction management. These results demonstrate that the increase in user satisfaction (e.g. utilization of information, satisfaction of cost, overall satisfaction) will improve efficient and effective construction management. Then, to improve user satisfaction, information and service quality which have significant influence on user satisfaction should be managed.

5.3. The relationship of intention to use PMIS and PMIS success

In the hypothesis, this research assumes that when improved PMIS quality leads to expanding usage, the greater effects are archived. According

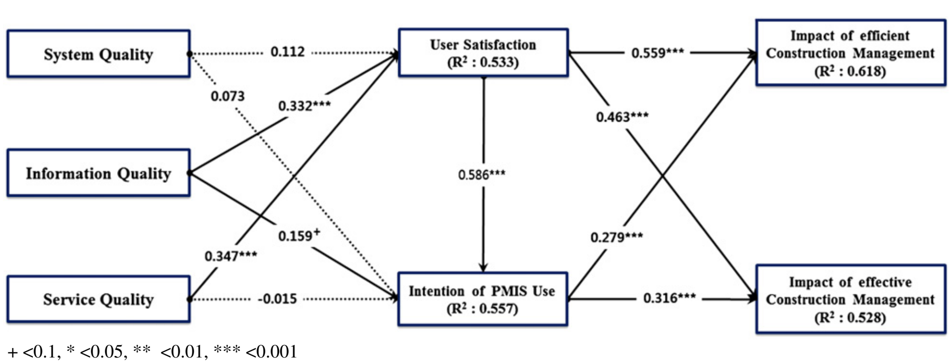

Fig. 7. Result of hypothesis testing.

Table 12
Direct, indirect and total effects.

	Total effect				Direct effect				Indirect effect			
	US	U	EFFI	EFFE	US	U	EFFI	EFFE	US	U	EFFI	EFFE
System quality	0.112	0.139	0.102	0.096	0.112	0.073	0	0	0	0.066	0.102	0.096
Information quality	0.332	0.353	0.284	0.265	0.332	0.159	0	0	0	0.194	0.284	0.265
Service quality	0.347	0.189	0.247	0.22	0.347	−0.015	0	0	0	0.204	0.247	0.22
User satisfaction	0	0.586	0.723	0.648	0	0.586	0.559	0.463	0	0	0.164	0.185
Intention of PMIS use	0	0	0.279	0.316	0	0	0.279	0.316	0	0	0	0

to the analysis results, intention of PMIS use (e.g. the intention to recommendation and the intention to reuse) has the strongest total effect on effective construction management. That is, the more expending the PMIS use within organization or between organizations, the more improving information sharing and collaboration. Ultimately, project success factors (such as a management area supported by PMIS) can be achieved. In the relationship between PMIS quality and intention of PMIS use, the direct effect by PMIS quality is lower than indirect effect by PMIS quality. In other words, it is that user satisfaction plays an important role as a parameter between PMIS quality and intention of PMIS use. Therefore, developers of PMIS should periodically conduct user evaluation and reflect their demands. Also, to increase intention of PMIS use, the developers of ASP based PMIS specially need to improve information quality.

5.4. The relationship of PMIS quality and PMIS success

Information quality contributed more to efficient and effective construction management than service quality. On the other hand, the effect of system quality on intention of PMIS use is very low and is nonexistent on user satisfaction. This means that, because the system environment (computer and internet) maintains a high level in the construction sites, system quality is not a critical factor for PMIS success. However, system quality is not consideration of PMIS developers but low priority of improvement. Therefore, the system quality is continually managed and maintained the current level. Any strategy established should take into consideration the effects of the system quality; otherwise it would be considered incomplete [91].

The results of this research propose a mechanism for achieving the success of an ASP based-PMIS by defining factors affecting PMIS success and measurement items of the factors and analyzing the relationship among the factors. In terms of the PMIS developer, they can understand quality factors and their importance to continuously improve PMIS and utilize them as a future guideline to enhance PMIS functions. Moreover, in terms of the PMIS user, they will be able to be used as a standard for evaluation aimed at selecting an appropriate construction PMIS to provide a better construction management. Our findings can provide some insights into related research since the investigation of PMIS success models is relatively new. However, the investigation is based on an information system in a particular country. Thus, the interpretation of the results should be confined to Korea or to countries with similar settings.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (2011-0015446).

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