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Discriminant Model of BIM Acceptance Readiness in a Construction Organization

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Abstract

Building Information Modeling (BIM) is a general term for technology that links project information to 3D object-based models that manage, exchange, and share data between project participants throughout the life cycle of a project. In line with this, an emphasis on BIM in the international construction market is expected to become even greater, focusing on advanced countries in construction such as the United States and Europe. The Korean domestic market is also faced with the introduction of BIM due to an influx of investment and an increased interest in introducing BIM and mandatory application of BIM. In the Korean domestic market, the rate of BIM introduction is high, while BIM user proficiency is low. Further, the ratio of users who abandon BIM utilization is rather high. This is mainly due to the introduction of BIM in a situation wherein the organizations are not ready for the various elements required to utilize BIM. This pattern creates limitations in obtaining the expected effects of BIM and results in reduced continued use due a decrease in BIM credibility. Therefore, this research aims to develop a Discriminant Model of BIM Acceptance Readiness in a Construction Organization to evaluate readiness for elements required to utilize BIM. To empirically verify the proposed model, we retrieved 164 completed questionnaires by construction organizations (such as contractors, architects, construction managers and engineers). Using SPSS 17.0, we conducted discriminant analysis. The validated model will increase awareness on the need to evaluate BIM acceptance readiness and predict BIM acceptance readiness.

Keywords: *Building Information Modeling (BIM), Technology Acceptance Model (TAM), BIM Acceptance Readiness, Discriminant Analysis*

1. Introduction

Building Information Modeling (BIM) allows building objects to express individual properties and recognizes their interrelationships to immediately reflect any changes in the building with respect to each aspect, and helps to produce better buildings faster and at lower planning, construction, and post-management costs (Kim, 2004). Interest in BIM is increasing in the construction industry, and use is gradually becoming an essential element rather than an option.

Accordingly, research both domestic and worldwide continues to develop application technologies that support BIM-based planning in maintenance and management, and the government is proposing guideline development and policies for BIM implementation. In Korea, the Public Procurement Service has published basic BIM Application Guidelines, and imposed on over 500 trillion public construction projects by 2016. Following this trend, the implementation of BIM in Korea is currently at 58%. However, the satisfaction of BIM users (48%) in Korea is lower than in other country (Japan, Germany, France (97%), Canada (87%), Brazil (85%), Australia and New Zealand (78%), USA (74%), England (59%)). Also, the number of non-BIM users (10%) who have previously used BIM, but then stopped was higher than in Europe (4%) and the USA (2%) (SmartMarket Report, 2012, 2013). This is mainly due to organizations not being ready for the various elements required to utilize BIM. This pattern creates limitations in obtaining the expected effects of BIM and results in reduced continued use due to a decrease in BIM credibility.

Parasuraman (2000) claimed that users' positive attitude and belief in technology are related to how prepared they are to use new technology, which they called 'technology readiness', and argued for the importance of user tendencies in accepting technology. Similarly, while BIM usage has many benefits for information management in the construction industry, the usage of BIM as new technology cause increased BIM user's resistance. The factors causing BIM user resistance consists of environmental factors for BIM use and organization-related factors or psychological factors of the users rather than technological factors. That is, if organizations are not ready for these factors, it is difficult for a BIM user to obtain the expected positive effects from BIM usage. Therefore, we have proposed BIM acceptance readiness

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as an organization's readiness with regard to various prerequisites favorable to utilization of BIM.

There are several evaluation models for BIM utilization such as the BIM Maturity Model, Interactive BIM Capability Maturity Model, BIM Proficiency Matrix and bimSCORE. The BIM Maturity Model is used to determine how well an organization uses BIM and evaluates results from use of BIM, explores effective BIM-related technological policies and technology development directions, and improves process environments. However, current evaluation models are limited by a focus on evaluating BIM quality and do not include measurement items to evaluate from both an individual and organizational perspective.

Therefore, this research aims to develop and validate a discriminant model of evaluating BIM acceptance readiness. This research process is shown in the following. First, we review the IS Success Model and Technology Acceptance Model (TAM) developed by other researchers and then propose the importance of BIM acceptance in the construction industry. Second, we define the concept of BIM acceptance readiness and propose measurement items for a theoretical discriminant model of BIM acceptance readiness based on a literature review. For empirical verification of the proposed model, a survey was conducted among construction-project participants that are experienced BIM users (construction managers, designers, contractors, and engineers), and the results of a discriminant analysis are presented. Forth, we validated the discriminant results by the proposed model using an independent-samples t-test. Finally, theoretical and managerial implications and directions for future research are discussed.

2. Literature Review

2.1 Barrier of BIM using in Construction Organization

Interest in BIM is globally increasing in the construction industry due to its benefits. Korea has also been trying to utilize BIM. In fact, it is no longer an option, but is becoming an essential element. Accordingly, studies in Korea and around the world are developing application technologies that support BIM-based planning for maintenance and management, and the government is proposing guideline development and policies for BIM implementation.

In Korea, despite the government's BIM usage expansion policy, the expansion of BIM usage is very slow. This is due to the introduction of BIM at a stage when many unresolved factors hinder proper adoption. Thus, the increase in BIM implementation rate tends to be short-lived, and the expected effects have been limited. Progress in use of BIM has often been discontinued due to low credibility.

To examine the factors that hinder the use of BIM, previous studies (Choi, 2010; Park *et al*., 2009; Lee *et al.*, 2007; SmartMarket Report, 2008, 2012) were analyzed and interviews were conducted at five sites that use BIM and five sites that do not, looking at the issues as described below (Lee and Yu, 2013).

- Unclear and un-validated benefits of BIM in ongoing practices
- Lack of familiarity with adopting this new technology
- Lack of supporting education and training to use BIM
- Lack of supporting resources (software and hardware) to use BIM tools
- Lack of effective collaboration between project stakeholders for modeling and model utilization
- Unclear roles and responsibilities for loading data into a model or databases and maintaining the model
- Lack of sufficient legal framework for integrating owners' view in design and construction.

To examine whether the deduced factors actually affect BIM use, BIM users (construction managers, designers, contractors, and engineers) were asked to evaluate various factors. In the results, they rated all the factors above 4 points out of 7. Therefore, all the deduced factors hinder BIM use in all types of organizations, and consist mostly of environmental factors for BIM use and organization-related factors or psychological factors of the users rather than technological factors.

Previous studies related to such factors include those of Meuter *et al.* (2005) and Lin and Hsieh (2007), who argued that the development of technologies benefits users, but also increases their frustration and anxiety. Also, Parasuraman (2000) claimed that users' positive attitude and belief in technology are related to how prepared they are to use new technology, which they called 'technology readiness', and argued for the importance of user tendencies in accepting technology. This was reflected in the development of a Technology Readiness Index (TRI) as an index of such technology readiness.

Similarly, in the construction industry, while BIM usage has many benefits for information management, the implementation of this new technology caused increased BIM user's anxiety. In this situation, it is difficult for a BIM user to obtain the expected benefits of BIM usage. Therefore, BIM acceptance is a factor that is important to consider and manage in terms of BIM user readiness.

2.2 Importance of BIM Acceptance for BIM Success

DeLone and McLean (1994) presented an IS success model with six factors related to the success of information systems through reviewing on IT investment assessment factors published from 1970s to 1980s.

Improvement of IS quality leads to satisfaction of IS and expansion of IS usage. Ultimately, this leads to an individual impact, and an organizational impact. That is, IS success is defined as an expectation effect gained by achieving an IS purpose through IS usage.

In this research, BIM success is defined as an improvement in individual performance and organizational performance gained

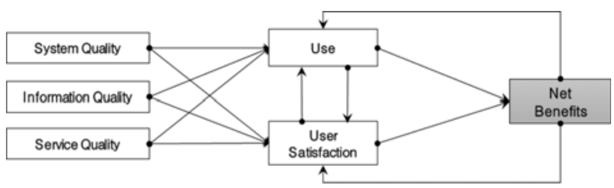

Fig. 1. DeLone and McLean IS Success Model

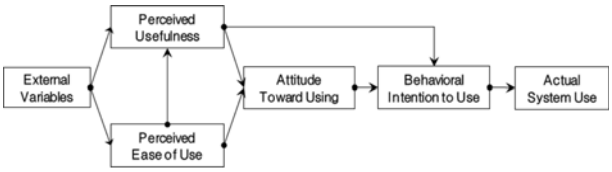

Fig. 2. Technology Acceptance Model

by integration management of required information throughout the lifecycle of a construction project. BIM success is achieved through the combined management of required information over all phases of construction projects. The combined management of necessary information over all phases of construction projects is based on the harmonious sharing of information and on cooperation. Moreover, information sharing and cooperation are based on the continued use and the expansion of BIM, not just by an individual, but by the entire organization. Due to BIM characteristics, individual acceptance and organizational acceptance have an impact on BIM success. In other words, BIM usage is a prerequisite to BIM success.

Typical theory related to acceptance and usage of new IS and services based on IT includes the Technology Acceptance Model (TAM). TAM was introduced by Davis (1989) and is an adaptation of the Theory of Reasoned Action (TRA) and the Theory of Planned Behavior (TPB) specifically tailored for modeling user acceptance of information systems.

The existing TAM, which was examined as a representative theory related to the selection and use of services based on new information systems and information technologies, is being studied by applying technologies mainly used in individual work (such as e-mail, databases, software, websites, wireless Internet technologies, and e-commerce, *et al.*). Acceptance of the technologies depends on user's choice and the user's choice depends on user's usefulness or ease of use. However, there are very few individuals with the authority to select information technologies for implementation in an organization. Thus, the use of information technology in an organization signifies its adaptation in an organizational context and has a passive significance. Such a passive situation is not determined by voluntarily selecting individual members, but by structural influence. This differs from past analysis looking at situations that lead to the establishment of a positive attitude towards information technology thru TAM.

Within the context of BIM, organizational properties are likely to be an important influencing factor that is in addition to technological properties. The literal meaning of the acceptance of a passive situation is identical to the meaning of the word acceptance with respect to TAM, but in truth, it has different meanings. In terms of BIM characteristics, a BIM user does not only use BIM tools for their own work, but also shares information thru BIM with other members of the organization. As such, it is important to consider factors affecting BIM acceptance from both an individual and organizational perspective. This requires an extension to TAM, which focuses only on individual technology acceptance.

3. Discrimination Model of BIM Acceptance Readiness

3.1 Research Model

We determined that one cause of low BIM expansion usage is that users accepted introduction of BIM in an unprepared state and did not achieve gains in improvement of individual and organizational performance. To resolve this problem, a construction organization needs to be ready in terms of several preparation factors required for successful BIM acceptance. If decision makers can know determine and be aware of key factors affecting BIM acceptance and whether or not there is BIM acceptance through the present level of various factors, they can establish an efficient and effective strategy for BIM acceptance in their organization. As such, a model is needed to identify and evaluate key factor affecting BIM acceptance and to determine whether or not there is BIM acceptance.

Therefore, in this research, we define the concept of BIM acceptance readiness for successful BIM implementation in construction organizations by deducing various factors that influence BIM acceptance. Subsequently, we propose a discriminant model composed of BIM acceptance factors using discriminant analysis. We also designed a research model to validate the relationship between BIM acceptance and BIM success (see Fig. 3).

The research model was composed in two steps. First, we classified a BIM acceptance group and a BIM non-acceptance group by using discriminant analysis ($H_{1\text{-}0}$, $H_{1\text{-}1}$). In terms of classifying groups using dependent variables, discriminant analysis is similar to logistic regression analysis and cluster analysis. However, discriminant analysis can draw a functional formula that is composed of dependent variables, which is in contrast to logistic regression analysis and cluster analysis. Groups with an independent variable are classified using a determinant score by a functional formula. In terms of drawing a functional formula, discriminant analysis is similar to regression analysis. While the dependent variable of regression analysis is a ratio scale, the dependent variable of discriminant analysis is a nominal scale. In other words, while the purpose of a regression

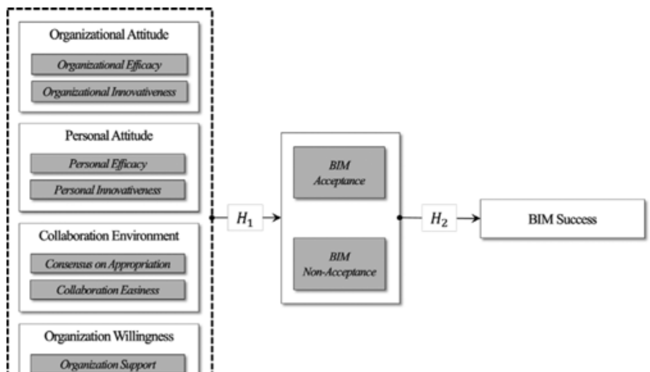

Fig. 3. Research Model

analysis is to draw a functional formula that can reduce variance of the dependent variable and estimate a dependent variable, the purpose of discriminant analysis is to draw a functional formula that can classify cases into groups defined as a dependent variable and estimate groups including cases. Second, we validated that the difference in BIM success between the BIM acceptance and BIM non-acceptance groups is significant by independent-samples t-test ($H_{2\text{-}0}$, $H_{2\text{-}1}$).

$H_{1:}$
- $H_{1\text{-}0}$: *Group centroids (mean discriminant scores) of BIM Acceptance group and BIM Non-Acceptance group make no difference.*
- $H_{1\text{-}1}$: *Group centroids (mean discriminant scores) of BIM Acceptance group and BIM Non-Acceptance group make a difference.*

$H_{2:}$
- $H_{2\text{-}0}$*: BIM success of BIM Acceptance group and BIM Non-Acceptance group make no difference.*
- $H_{2\text{-}1}$: *BIM success of BIM Acceptance group and BIM Non-Acceptance group make a difference*

3.2 Data Collection

The data obtained from BIM users which have experience with BIM use and BIM related education or training. We have added respondent average experience with BIM use and BIM related education or training because the utilization period in practice in Korea has been relatively brief, and average experience with BIM use (approx. 1 year) is also relatively short. Thus we supplemented this limitation thru questions about BIM related education or training (approx. 24.12 hours). The data is identical with the used data in our previous research (Lee and Yu, 2013, 2015).

3.3 Discriminant Analysis of BIM Acceptance

3.3.1 Key Factors Affecting BIM Acceptance

This research was conducted to define BIM acceptance by analyzing previous research on the acceptance of BIM or information technology in the construction industry, and initially selected a total of 22 key factors affecting BIM acceptance. For content validity of 22 items, we conducted face-to-face interviews with five experts. The experts (research, designer, contractor, BIM Service Company, and engineer) had more than five years of average experience with BIM use and ten years of average experience with the construction industry. Because the utilization period in Korea is short, the average experience of BIM use (approx. 5 years) was also relatively brief. Thus we supplemented this limitation thru additional questioning about level of BIM use. All the experts were all able to understand BIM information structure and perform management tasks using BIM. The experts were also asked to review the questionnaire for redundancy and accuracy. After the interview, all 22 key factors were selected. The next step involved testing construct validity using Exploratory Factor Analysis (EFA) and reliability of the factors using a Cronbach's coefficient alpha value. Hair *et al*. (1998) argued that an appropriate sample size should be at least 4-5 times the number of variables. In this research, the sample size was five times

Table 1. Descriptive Statistics of the Respondents' Characteristics (N=164)

Measure		Frequency	%
Sector of the respondent' Organization	Designer	51	31.1%
	CM	40	24.4%
	Contractor	33	20.1%
	Engineer	36	22.0%
		4	2.4%
Total		164	100%
Respondent's average experience	Construction Industry	Approx. 6 years	
	BIM	Approx. 1 years	
BIM related education or training		Approx. 24.12 hours	

- Collection period : April 11 and June 12, 2012 (by e-mail)
- Scale: 7-point Likert scale

Table 2. Results of Testing Construct Validity and Reliability

Factor	Measurement Items	Factor Loading	Eigen Value	Cumulative %	Cronbach' α
1	U10	0.840	10.229	46.497	0.948
	U11	0.798			
	U12	0.774			
	U9	0.771			
	U7	0.762			
	U8	0.733			
2	U6	0.883	3.017	60.210	0.938
	U5	0.859			
	U4	0.853			
	U3	0.850			
	U2	0.848			
	U1	0.814			
3	E9	0.792	1.607	67.516	0.851
	E8	0.776			
	E10	0.759			
	E7	0.717			
	E6	0.529			
4	E4	0.854	1.238	73.143	0.861
	E5	0.774			
	E3	0.667			
	E2	0.577			
	E1	0.540			
Kaiser-Meyer-Olkin measure of sampling adequacy					0.895
Bartlett's test of Sphericity		Approx. Chi-Square			3099.315
		df.			231
		Sig.(p)			0.000

* Acceptable level
1) the KMO index : above 0.6 (Kaiser, 1970)
2) Bartlett's test of sphericity : less than 0.05 (Bartlett, 1954)
3) Eigenvalues: greater than 1 (Aksorn and Hadikusumo, 2008; Li *et al.*, 2005; Norusis, 1992).
4) Factor loadings: greater than 0.5 (Aksorn and Hadikusumo, 2008; Li *et al.*, 2005, Norusis, 1992).
5) Cronbach's α value : above 0.6 (Nunnalyy, 1978)

larger than the number of variables, which was sufficient for factor analysis. And we used principal component analysis with varimax rotation as the method for data analysis. The analysis results of construct validity and reliability are shown in Table 2.

Four factor groups were identified by using factor analysis and Cronbach's α: Organizational Attitude (6 items), Personal Attitude (6 items), Collaboration Environment (5 items), and Organization Willingness (5 items).

3.3.1.1 Factor 1: Organizational Attitude

This component, which accounted for 46.497% of the total variances between key factors, was relatively more important than the other four components. Items included in this component are defined as 'Organizational Attitude'. This factor indicated that organizational competency is an important issue for BIM acceptance.

'Organizational Attitude' can be divided into two groups: 'Organizational Innovativeness' (U10, U11, U12), and 'Organizational Efficacy' (U7, U8, U9).

Organizational Innovativeness: the willingness of an organization to try out any new information technology.

Organizational Efficacy: beliefs that BIM is used for cooperative work in an organization.

3.3.1.2 Factor 2: Personal Attitude

This component ranked second among the four components. We defined this component as 'Personal Attitude'. 'Personal Attitude' factors can be divided into two groups: self-efficacy (U1, U2, and U3), and personal innovativeness (U4, U5, and U6).

Self-Efficacy: beliefs that BIM is used for individual's task of BIM user.

Personal Innovativeness: the willingness of an individual to try out any new information technology.

3.3.1.3 Factor 3: Collaboration Environment

This component ranked third among the four components. 'Collaboration Environment' factors can be largely divided into two groups: 'Consensus on Appropriation' (E6, E7), and 'Ease of Collaboration' (E8, E9, E10).

Consensus on Appropriation: The agree about how to jointly use BIM utilization

Ease of Collaboration: The organization's recognition that BIM utilization is not difficult

3.3.1.4 Factor 4: Organization Willingness

This component was the lowest ranked among the four components. We defined this component as 'Organization Willingness'. 'Organization Willingness' factors can be largely divided into two groups: 'Organization Support' (E1, E2, E3), and 'Organization Pressure' (E4, E5).

Organization Support: organized supports such as resource, education, and incentives for BIM utilization.

Organization Pressure: the forcing superiors, colleagues or the competitive environment to use BIM.

The measurement items for key factors affecting BIM Acceptance are as follows (see Table 3).

Table 3. Measurement Items for Key Factors Affecting BIM Acceptance (Lee and Yu, 2013; 2015)

Key Factors		Measurement item
Organizational Attitude	Organizational Efficacy	My organization doesn't have any resistance to using BIM.
		My organization is familiar to BIM tools.
		My organization understands the benefits of using BIM.
	Organizational Innovativeness	My organization doesn't have psychological resistance to using new IT
		My organization has technical capability of using new information technology.
		My organization is aggressive pushing to use new information technology.
Personal Attitude	Personal Efficacy	I don't have any resistance to using BIM.
		I am familiar with BIM tools.
		I understand the benefits of using BIM.
	Personal Innovativeness	I don't have psychological resistance to using a new information technology.
		I have technical capability of using a new information technology.
		I am aggressive about using a new information technology.
Collaboration Environment	Consensus on Appropriation	The members of the organization have conformity on the tasks that apply BIM which is set by the organization.
		The members of the organization have conformity on how to apply BIM (such as related work guideline s and rules) which is set by the organization.
	Collaboration Easiness	It is easy to learn how to cooperate with BIM.
		If we adopt BIM, it is easy to exchange information among stakeholders.
		The guideline for collaboration with BIM is defined so that we could follow easily.
Organization Willingness	Organization Support	My organization supports enough resources (HW and SW) for BIM utilization.
		My organization provides proper education/training for BIM utilization.
		My organization provides incentives if we adopt or utilize BIM.
	Organization Pressure	My organization forces us to use BIM by setting up policies and regulations.
		I am required to use BIM by superiors and colleagues.

Table 4. Group Statistics

Groups	Key Factors	Mean	Std. Deviation	Valid N (listwise)	
				Unweighted	Weighted
BIM Non-Acceptance	Personal Efficacy	1.530	0.370	86.000	86.000
	Personal Innovativeness	1.527	0.389	86.000	86.000
	Organizational Efficacy	1.330	0.382	86.000	86.000
	Organizational Innovativeness	1.311	0.415	86.000	86.000
	Organization Support	1.187	0.390	86.000	86.000
	Organization Pressure	1.709	0.613	86.000	86.000
	Consensus on Appropriation	1.770	0.544	86.000	86.000
	Collaboration Easiness	1.249	0.346	86.000	86.000
BIM Acceptance	Personal Efficacy	2.078	0.307	78.000	78.000
	Personal Innovativeness	2.091	0.304	78.000	78.000
	Organizational Efficacy	1.845	0.424	78.000	78.000
	Organizational Innovativeness	1.856	0.431	78.000	78.000
	Organization Support	1.597	0.455	78.000	78.000
	Organization Pressure	2.157	0.820	78.000	78.000
	Consensus on Appropriation	2.301	0.643	78.000	78.000
	Collaboration Easiness	1.458	0.432	78.000	78.000
Total	Personal Efficacy	1.791	0.438	164.000	164.000
	Personal Innovativeness	1.795	0.450	164.000	164.000
	Organizational Efficacy	1.575	0.477	164.000	164.000
	Organizational Innovativeness	1.570	0.502	164.000	164.000
	Organization Support	1.382	0.469	164.000	164.000
	Organization Pressure	1.922	0.751	164.000	164.000
	Consensus on Appropriation	2.023	0.648	164.000	164.000
	Collaboration Easiness	1.349	0.402	164.000	164.000

3.3.2 Result of Discriminant Analysis

We performed discriminant analysis to confirm that the proposed key factors affecting BIM acceptance are discriminant criteria for BIM acceptance or non-acceptance, then drew a discriminant function that is a linear combination of the proposed key factors affecting BIM acceptance to discriminant whether or not there was BIM acceptance, and subsequently, validated the classification accuracy of the discriminant function.

In the research, eight key factors (Organizational Efficacy, Organizational Innovativeness, Self-Efficacy, Personal Innovativeness, Consensus on Appropriation, Ease of Collaboration, Organization Support, and Organization Pressure) were used as discriminant variables for BIM acceptance or non-acceptance. And we defined BIM acceptance or non-acceptance base on Rogers' five stages in the decision innovation process (Rogers, 1983). 'Knowledge-persuasion-decision' was defined as 'BIM non-acceptance' and 'implementation-confirmation' was defined as 'BIM acceptance'. The mean and standard deviation of the key factors affecting BIM acceptance of cases included a BIM acceptance group and a BIM non-acceptance group discriminated by discriminant analysis. This is shown in the following (see Table 4).

Table 5 provides strong statistical evidence of significant differences between means of BIM acceptance and BIM non-acceptance groups for self-efficacy and personal innovativeness, which produced very high values of F.

Table 5. Results of Testing Equality of Group Means

Key Factors	Wilks' Lambda	F	Sig.
Personal Efficacy	0.606	105.468	0.000
Personal Innovativeness	0.605	105.773	0.000
Organizational Efficacy	0.707	67.050	0.000
Organizational Innovativeness	0.705	67.876	0.000
Organization Support	0.808	38.559	0.000
Organization Pressure	0.911	15.862	0.000
Consensus on Appropriation	0.832	32.800	0.000
Collaboration Easiness	0.932	11.734	0.001

This provides information on each of the discriminate functions that are produced. The maximum number of discriminant functions produced is the number of groups minus 1. As we are only using two groups here, namely 'BIM acceptance' and 'BIM non-acceptance", only one function is displayed.

The significance of a discriminant function can also be validated using an eigenvalue, canonical correlation and Wilks' λ. Eigenvalues should be greater than 1, thus our value of 1.187 was satisfactory. Canonical correlation means a correlation between the predictors and the discriminant function. The criteria of canonical correlation value for good discriminant functions is 1 or above, thus our value was 0.737 and satisfactory. Also, Wilks' λ is verification of difference between groups by discriminant

Table 6. Results of Testing Significance for Determinant Function

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation	Wilks' Lambda	x^2
1	1.187	100.000	100.000	0.737	0.457***	123.664

***p<0.001, **p<0.05

function. In verification, a null hypothesis that means of groups make no difference should be rejected. A lower value of Wilks' λ reflects a higher explanation of discriminant function; our value was 0.457 and the significant value was less than 0.000 ($p < 0.05$).

In summary, the results of these tests confirm the significance of the discriminant function (see Table 6). This means that the discriminant ability of the BIM acceptance factors was relatively high.

Standardized canonical discriminant function coefficients reflect the relative contribution of predictors. The higher the absolute value of the coefficient, the higher the contribution to discriminating groups. As a result, personal Innovativeness and Collaboration Ease were the strongest in discriminant power. In comparison, canonical discriminant function coefficients are an absolute contribution of predictors and coefficients of significant variables in discriminant function. The coefficients do not reflect the relative importance of the independent variable. Table 7 shows discriminant function coefficients for discriminating BIM acceptance or BIM non-acceptance groups.

Therefore, the discriminant functions are as follows:

$$f = 1.190 \times \text{Personal Efficacy} + 1.272 \times \text{Personal Innovativeness} + 0.614 \times \text{Organizational Efficacy} + 0.663 \times \text{Organizational Innovativeness} + 0.403 \times \text{Organization Support} - 0.021 \times \text{Organization Pressure} + 0.381 \times \text{Consensus on Appropriation} - 1.143 \times \text{Collaboration Easiness} - 6.170$$

These discriminant functions are used for existing cases, and also to predict new cases. Therefore, the discriminant function for discriminating BIM acceptance or BIM non-acceptance groups using discriminant analysis is the proposed BIM acceptance prediction model.

A further approach for interpreting discriminant analysis results is to describe each group in terms of a profile, using the group means of the predictor variables. These group means are called Group centroids. These are displayed in the Group Centroids Table (see Table 8). In our research, BIM acceptance has a mean of 1.137, while BIM non-acceptance produced a mean of -1.031. Cases with scores near a centroid are predicted as belonging to that group.

Finally, there is the classification phase. The classification table, also called a confusion table, is simply a table in which the rows are the observed categories of the dependent variables and the columns are the predicted categories. In Table 9, the classification results reveal that 87.8% of respondents were classified correctly into BIM acceptance or BIM non-acceptance groups. This overall predictive accuracy of the discriminant

Table 7. Standardized Canonical Discriminant Function Coefficients and Canonical Discriminant Function Coefficients

Key Factors	Standardized Canonical Discriminant Function Coefficients	Canonical Discriminant Function Coefficients
Personal Efficacy	0.406	1.190
Personal Innovativeness	0.447	1.272
Organizational Efficacy	0.247	0.614
Organizational Innovativeness	0.281	0.663
Organization Support	0.170	0.403
Organization Pressure	-0.015	-0.021
Consensus on Appropriation	0.226	0.381
Collaboration Easiness	-0.445	-1.143
Constant	-	-6.170

Table 8. Mean of Discriminant Score by Group (Group Centroids)

Groups	Functions at Group Centroids
BIM Non-Acceptance	-1.031
BIM Acceptance	1.137

Table 9. Casewise Statistics

		Groups	Predicted Group Membership		Total
			BIM Non-Acceptance	BIM Acceptance	
Original	Count	BIM Non-Acceptance	77	9	86
		BIM Acceptance	11	67	78
	%	BIM Non-Acceptance	89.53	10.47	100
		BIM Acceptance	14.10	85.89	100
Cross-validated	Count	BIM Non-Acceptance	76	10	86
		BIM Acceptance	15	63	78
	%	BIM Non-Acceptance	88.37	11.63	100
		BIM Acceptance	19.23	80.769	100

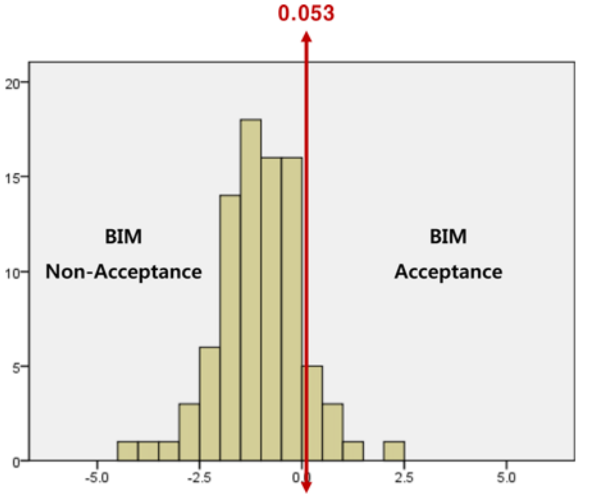

Fig. 4. BIM non-Acceptance (Mean: -1.031, Std.Dev.=1.05, N=86)

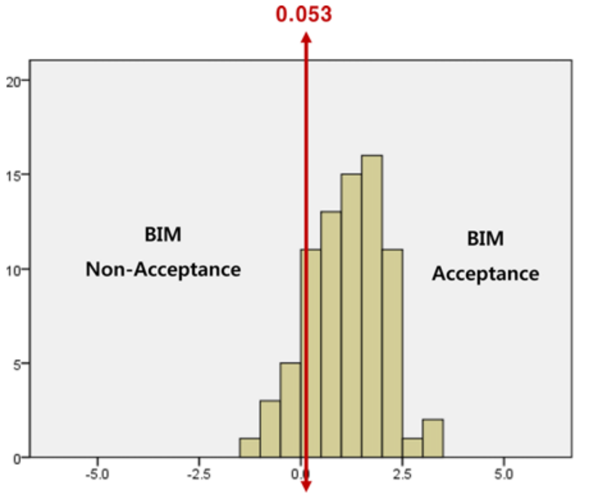

Fig. 5. BIM Acceptance (Mean: 1.137, Std.Dev.=0.941, N=78)

function is called the hit-ratio. BIM non-acceptance was classified with slightly better accuracy (89.53%) than BIM acceptance (85.89%).

Histograms (Fig. 4 and Fig. 5) are alternative ways of illustrating the distribution of the discriminant function scores for each group. The very minimal overlap of the graphs was based on the mean of both group centroids. That is, cases with a discriminant score higher than 0.053 can be predicted as being in the BIM acceptance group.

$$\text{Mean of both group centroids} = \frac{-1.031 + 1.137}{2} = 0.053$$

Table 10.Measurement Items for BIM Success (Lee and Yu, 2015)

BIM Success	Measurement item
Individual Performance	Task speed is improved by using BIM
	Task accuracy is improved by using BIM
	Communication among stakeholders is improved by using BIM
	Information is systemically managed by using BIM
Organizational Performance	Time management is effectively conducted by using BIM.
	Cost management is effectively conducted by using BIM.
	Quality management is effectively conducted by using BIM.
	Safety management is effectively conducted by using BIM.
	Environmental management is effectively conducted by using BIM.

3.4 BIM Acceptance and BIM Success

We classified factors into BIM acceptance or BIM non-acceptance groups using discriminant analysis in section 3.3. Using an independent-samples t-test, we validated that the difference in BIM success between the BIM acceptance and BIM non-acceptance groups was significant (see Fig. 3).

We defined individual performance and organizational performance as BIM success. The measurement items for BIM success are as follows (see Table 10).

According to Levene's F Test for equality of variances, the Sig. value is more than 0.05, we accept the null hypothesis for the assumption of homogeneity of variance and use the data results associated with the 'equal variances assumed'. And according to t-test for equality of means, p value was less than our alpha of 0.05. We reject the null hypothesis in support of the alternative hypothesis, and conclude that BIM acceptance groups and BIM non-acceptance groups differed significantly on BIM success. By examining the group means for this sample of subjects, we see that BIM acceptance groups (with a mean of 5.199) performed significantly higher on BIM success than did BIM non-acceptance groups (with a mean of 3.762). Therefore, an organization must accept BIM for a higher probability of success.

The analysis results of the independent-samples t-test are shown in Table 11.

4. Conclusions

We proposed BIM acceptance readiness as an index that can determine readiness for BIM use, and a Discriminant Model of BIM Acceptance Readiness that can be used to evaluate BIM acceptance readiness. The results of discriminant analysis show

Table 11. T-test Results

BIM success	t	df	p	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Individual Performance	-8.006	162	0.000^{***}	-1.546	0.193	-1.927	-1.165
Organizational Performance	-7.180	162	0.000^{***}	-1.348	0.188	-1.719	-.978

*** p<0.001, ** p<0.05

that the discriminant function that was composed of key factors affecting BIM acceptance was significant. That is, the proposed key factors affecting BIM acceptance contribute to a discriminant model of BIM acceptance readiness. Furthermore, the discriminant accuracy of the proposed model was 87.8% and was relatively high. In Table 4, the mean of Self-Efficacy, Personal Innovativeness, Organization Pressure, and Consensus on Appropriation of cases included in the BIM acceptance group was high. In contrast, the mean of Organization Support and Ease of Collaboration was low.

These results imply the following. Because BIM use in Korea is at an early stage and BIM is a new technology, BIM users that are familiar with previous work methods need to make many changes to use BIM and organizational pressure rather than an expectation of voluntary usage is required to promote BIM usage. Currently, however, BIM is typically used for part of a project or task and by a BIM team rather than by all members of an organization, thus the required level of organizational support and collaboration ease is low. This research provides several important implications about successful acceptance of BIM.

4.1 Importance of BIM acceptance for BIM Success

Individual and organizational BIM success is achieved by the combined management of required information over all phases of a construction project. The combined management of necessary information over all phases of construction projects is based on a continuous sharing of information and on cooperation; and information-sharing and the cooperation are based on the continued use and expansion of BIM, not by an individual, but by the entire organization. To achieve this, individuals and organizations must positively recognize and accept the value of BIM, support it by using it, and contribute to improvement of the technology. To verify this, an independent sample t-test was used to analyze the significance of the difference in enhanced achievements BIM usage between the BIM acceptance group and the BIM non-acceptance group using discriminant analysis. The results of the t-test showed a statistically significant difference in the average BIM success rates of the two groups. Accordingly, BIM acceptance, such as through creation of an environment suitable for BIM use and promotion of awareness of the value of BIM among individuals and organizations, is a checkpoint that must be continually managed and examined for BIM success, which shall enhance individual and organizational performance through combined management of information.

4.2 Usefulness of Discriminant Model for BIM Acceptance Readiness

The proposed model can be utilized to evaluate BIM Acceptance Readiness by discriminating whether or not BIM Acceptance exists in a construction organization. For organizational decision-makers, the model can assist in helping to better understand the key factors affecting BIM acceptance in an organization and how to promote the establishment of effective and efficient improvement strategies for BIM acceptance. Moreover, in terms of the BIM user, the model helps to provide a positive perception about BIM use in a better environment, and expectations of business efficiency improvement. Finally, in terms of owners, they will be able to be use this data as a guide to objectively evaluate the BIM acceptance readiness of stakeholders and observe project performance improvement through BIM usage.

4.3 Limitations and Future Research

This study had several limitations. The results of the proposed model may differ based on tendencies of the respondents. Thus, there is a need to consider a method that can amend the ambiguity of subjective judgment or define an evaluation index for each evaluation sector to achieve objective evaluation results. There is also a need to consider multi-criteria decision-making, such as thru an improvement priority calculation to allow the use of the results of the proposed model in actual decision-making processes.

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