Interdependence between Structural Engineering and Construction Management
Edited by Ozevin, D., Ataei, H., Modares, M., Gurgun, A., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-6-2

KEY KNOWLEDGE ENABLER FACTORS FOR EFFECTIVE BIM IMPLEMENTATION IN CONSTRUCTION ORGANIZATIONS

VEERASAK LIKHITRUANGSILP and TRAN TUAN KIET

Dept of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand

Building information modeling (BIM) is an innovative approach that is widely used to overcome various challenges in the construction industry. Current BIM implementation mainly focuses on information management, but puts very limited effort on knowledge. That is, the current BIM practice is information-centered, but it is not mature enough to generate and capture experiential knowledge. In addition, knowledge management (KM) is limitedly adopted for BIM implementation. Based on this paper's rigorous literature review as well as a survey questionnaire, nine knowledge enablers and 52 knowledge enabler factors for BIM implementation (KEFBIs) are identified. In this paper, we deploy ISM fuzzy MICMAC to identify and classify the key KEFBIs that influence BIM implementation by contractors. The results can guide contractors to avoid difficulties while adopting BIM so that they can plan and allocate their resources optimally.

Keywords: Knowledge management, Delphi, Mean score, Interpretive structural modeling, ISM, Fuzzy MICMAC.

1 INTRODUCTION

Construction is a major sector of every nation's economy. It is vital to the creation of material and fixed assets for many countries (Flanagan and Norman 1993). However, construction projects always encounter many problems in both maintaining their position and meeting the needs of customers. This is because there have been limited innovations in this industry. Recently, BIM has been a new, innovative technology that can address various challenges in construction. BIM changes the execution of construction projects and is useful for various issues in construction management (Bryde *et al.* 2013). It can support the processes of design, scheduling, and budgeting of built assets (Gu and London 2010) because of the visualization of BIM models (Succar and Mohamad 2015).

2 BIM IMPLEMENTATION IN CONSTRUCTION ORGANIZATIONS

BIM is both a technological and organizational innovation (Succar and Mohamad 2015). As an organizational innovation, BIM implementation involves the changing of a firm's values, culture, structure, and infrastructure (Dossick and Neff 2010). BIM implementation encounters many difficulties because it encompasses change management and the resistance of individuals. Thus, it is very challenging to achieve full benefits of BIM in mainstream construction projects and companies. (Gu and London 2010).

As construction companies begin implementing BIM in their organizations, they must comprehend the factors that influence knowledge for BIM implementation, which are known as *knowledge enablers for BIM implementation* (KEBIs). Because enablers are the driving forces in carrying out BIM implementation, they generate knowledge in organizations and motivate group members to share their knowledge and experiences among one another. They allow organizational knowledge to grow concurrently and systematically (Stonehouse and Pemberton 1999). This paper identifies key KEFBIs for effective BIM implementation of contractors. The results can help contractors appreciate KEFBIs that are vital for the BIM implementation process.

3 LITERATURE REVIEW

Knowledge enablers are referred to as the key factors that determine the effectiveness of knowledge management (KM) implementation in an organization, and are the driving forces that solidify KM (Yeh *et al.* 2006). In other words, knowledge enablers can be viewed as critical success factors of KM (Hung *et al.* 2005). According to Dang *et al.* (2018), knowledge enabler factors (KEFs) can be used to measure the manageability of knowledge in organizations as well as the appropriateness of organizational mechanisms for intentionally and consistently fostering knowledge. Knowledge enablers, or enablers of BIM, have been investigated in some previous studies (e.g., Lee and Choi 2003, Teeragetgul and Charoenngam 2006, Dossick and Neff 2010, Arayici *et al.* 2011, Dang *et al.* 2018). However, so far, KEFBIs have not been investigated at the organization level of construction companies. Thus, this paper focuses on identifying KEFBIs (i.e., the items under KEBIs) at the organization level of construction companies.

4 RESEARCH METHODOLOGY

Figure 1 displays the research framework adopted for this paper. The two main stages are: the identification of KEFBIs in contractors and the identification of the contextual relationship among KEFBIs in contractors.

4.1 Delphi Method

In this paper, the Delphi method is used to gather responses through a consensus among a group of selected experts. The six experts have doctoral degrees in construction management and have more than ten years of work experience in construction, with at least five-year experience in BIM or KM. They were invited to participate in a series of discussions on the preliminary KEBIs and lists of KEFBIs. The experts were requested to review the appropriateness and adequacy of the potential KEBIs and KEFBIs in the context of contractors.

4.2 Questionnaire Survey

The questionnaire survey consisted of two steps. First, a preliminary questionnaire was sent to the experts. They were asked to rate the performance of each KEFBI on the Likert scale from 1 (very low) to 5 (very high). After the questionnaire characteristics were achieved among most experts, the final questionnaire was conducted and used to collect data. The survey focused only on the contractors in Vietnam. The respondents evaluated the performance of 52 KEFBIs in their firms. After two months, 63 responses were received. We eliminated some incomplete and invalid responses such as unidentified respondents and the respondents having less than one year in BIM fields. Finally, 59 responses were considered valid and used for further analyses.

4.3 Data Analysis

Mean score, which is a widely applied method, was used to calculate the mean values of KEFBIs. The ranking of KEFBIs helps contractors understand the importance of KEFBIs. Different sizes of organizations have different organizational and managerial structures, as well as different means of knowledge management (Dang *et al.* 2018). The mean values and ranking of KEFBIs are determined for two groups: small and medium contractors (SMCs) and large contractors (LCs). Per our rigorous literature review, nine KEBIs and 52 KEFBIs are listed in Table 1.

Table 1. Definitions of KEBIs and KEFBIs.

Code	Definition	References
SL	**Strategy and leadership**	1,2,3,4,5
SL1 to SL11	Clear or written policy on BIM implementation; Culture to promote BIM knowledge sharing; Strategic alliance to acquire BIM knowledge; Programs to improve BIM staff; Facilitating to gain BIM knowledge through experiential learning; Criteria for assessing BIM staff performance; Supportive supervisor management; Good leaders; Company leaders readiness for change; Developing knowledge management system; Defining company vision and mission clearly.	5,6,7,8,9
F	**Formalization**	5,6
F1 to F5	BIM implementation activities being covered by some formal procedures; Formal or planning contacts and communication; Ignoring regulations and reaching informal agreements; Making own regulations on the BIM implementation process; Setting benchmarking metrics for BIM implementation.	5,6,7
D	**Decentralization**	5,6,10
D1 to D5	Taking action without supervisor; Encouraged to make own decisions; Making decisions without refer others' experience; No need to ask supervisor before action; Making decisions without their supervisor's approval.	5,6,10
C	**Collaboration**	5,7
C1 to C6	Satisfied with level of collaboration; Willingness to help, support; Willingness to collaborate across organizational units; Willingness to admit responsibility for mistakes or failure; Open communication; Information sharing	5,6,7,8, 10
T	**Trust**	5,6,7
T1 to T6	BIM staff are generally trustworthy; Having reciprocal faith in other' intentions and behavior; Having reciprocal faith in others' ability; Having reciprocal faith in others' behaviors to work toward organizational goals; Having reciprocal faith in others' decision toward organizational interests than individual interests; Having relationships based on reciprocal faith.	5,6,7
L	**Learning**	5,6,12
L1 to L5	Provide various formal training programs on BIM; Provide opportunities for informal individual development other than formal training; Encourage people to attend BIM seminars, symposia; Provide various BIM programs such as clubs and community gatherings; Satisfied by the contents of BIM training or self-development programs.	5,6,7
I	**Incentive**	5,7,13
I1 to I4	Good teamwork is recognized and awarded; Provide opportunities for professional development; Provide monetary incentives; Provide non-monetary incentives (promotion).	5,7
IT	**Information technology**	5,6,7,14,15
IT1 to IT5	Provide IT support for collaboration among members; Provide IT support for communication among members; Provide IT support for searching and accessing information needs; Provide IT support for simulation and prediction; Provide IT support for systematic storing.	5,6,7
IS	**Individual skills**	5,6,7
IS1to IS5	Understanding others' tasks; Suggestions about others' tasks; Communication ability with various groups; Specialists on BIM fields; Performing their own tasks effectively without regard to environmental changes	5,6,7

References:(1) Pan and Scarbrough 1998,(2) Yeh *et al.* 2006,(3) Ho 2009,(4) Sin *et al.* 2009,(5) Dang *et al.* 2018,(6) Lee and Choi 2003,(7) Teeragetgul and Charoenngam 2006,(8) Dossick and Neff 2010 (9) Arayici *et al.* 2011,(10) Lee *et al.* 2012,(11) Homayouni *et al.* 2010,(12) Bixler 2002,(13) Wu 2012,(14) Lee and Kim 2001,(15) Hung *et al.* 2005.

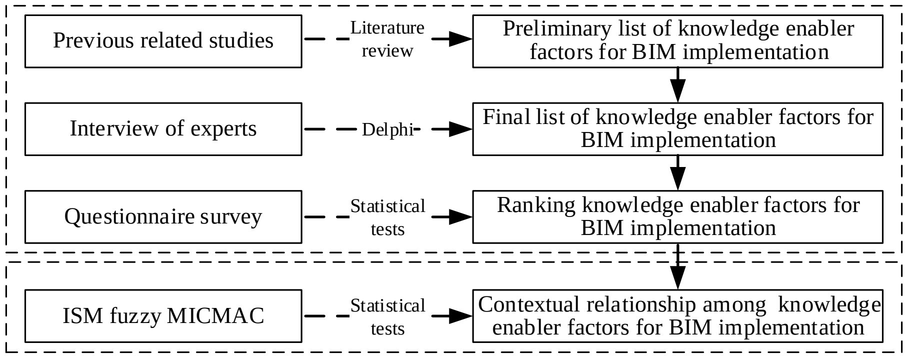

Figure 1. Research framework.

In addition, to examine the agreement within an individual group on the ranking of KEFBIs, whether the ranking orders of the two aforementioned groups are related, and whether the mean values of each item rated by the two aforementioned groups are different, Kendall's coefficient of concordance, Spearman's coefficient of rank correlation, and T-test were applied, respectively.

Subsequently ISM, which is a well-established methodology for identifying relationships among specific items (Attri et al 2013), was used to investigate the interrelationships among top ten knowledge enabler factors for BIM implementation of contractors. However, KM for BIM implementation of contractors is very complex; the relations among these factors are quite diverse. To consider the strength of relations and increase the sensitivity of MICMAC analysis, a fuzzy additional input of possibility of interaction among the KEFBIs was adopted.

5 RESULTS

5.1 Ranking of Knowledge Enabler Factors for BIM Implementation

Table 2 presents the ranking of the top ten KEFBIs, as well as the results of Kendall's coefficient (K-value) and T-test. The results of the ranking identify the KEFBIs in the two aforementioned groups. The company leaders' readiness for change (SL9) and the willingness to help and support (C2) are ranked first and second by both SMCs and LCs. It indicates that SL9 and C2 are evaluated as the most important KEFBIs for contractors. As a result, strategy and leadership (SL) and collaboration (C) are KEBIs that contractors should pay attention when implementing BIM.

The K-values for the ranking of the two groups are 0.091 and 0.197. It can be concluded that the response consensus within each group is achieved. The computed Spearman rank correlation coefficient between two groups is 0.622. It can be inferred that there are strong agreements among groups on ranking 52 KEFBIs. The results of T-test show that, at the significance level of 5 percent, there is no significant difference in the ratings of the two groups.

5.2 ISM Fuzzy MICMAC Analysis for Top Ten KEFBIs

Figure 2 presents the ISM models and four groups according to these dependent and driving powers of the top ten KEFBIs. From the ISM model, it has been observed that SL9 is at the first level of the ISM model. This KEFBI can be used to define the company vision and mission clearly (SL11) and strategic alliance to acquire BIM knowledge (SL3). SL11 and SL3 will provide programs to improve BIM staff (SL4), and provide opportunities for professional development (I2). SL11 and SL3 are at level two of ISM model. Level three in the ISM model contains SL4 and I2. SL4 increases the willingness to admit responsibility for mistakes or failure

(C4), which forms level four of the ISM model. If all the four levels of KEFBIs are implemented in the organization, then it leads to achieve the willingness to help, support (C2), having reciprocal faith in others' decision toward organizational interests than individual interests (T5), the willingness to collaborate across organizational units (C3), and the culture to promote BIM knowledge sharing (SL2), which are at level five.

Table 2. Top ten and results of Kendall's coefficient, T-test for KEFBIs.

Rank	SMCs (n=30)		LCs (n=29)		Overall (n=59)		T-test	
	KEFBI	Mean	KEFBI	Mean	KEFBI	Mean	F-value	p-value
1	SL9	4.00	SL9	4.07	SL9	4.03	1.012	0.319
2	C2	3.93	C2	4.07	C2	4.00	1.477	0.229
3	IT1	3.83	C3	4.07	C3	3.92	0.580	0.449
4	C5	3.83	SL2	4.03	SL11	3.88	2.109	0.152
5	SL11	3.80	SL3	4.03	C5	3.88	0.028	0.868
6	C3	3.77	SL4	4.03	C4	3.88	0.291	0.592
7	C1	3.77	C4	4.03	SL4	3.85	0.264	0.610
8	C4	3.73	T5	3.97	IT5	3.80	1.592	0.212
9	SL8	3.73	SL11	3.97	SL3	3.80	2.963	0.091
10	C6	3.73	I2	3.97	T5	3.80	3.845	0.055
K-value	0.091		0.197		0.119			
Chi-square	139.683		260.756		339.491			
p-value	0.000		0.000		0.000			

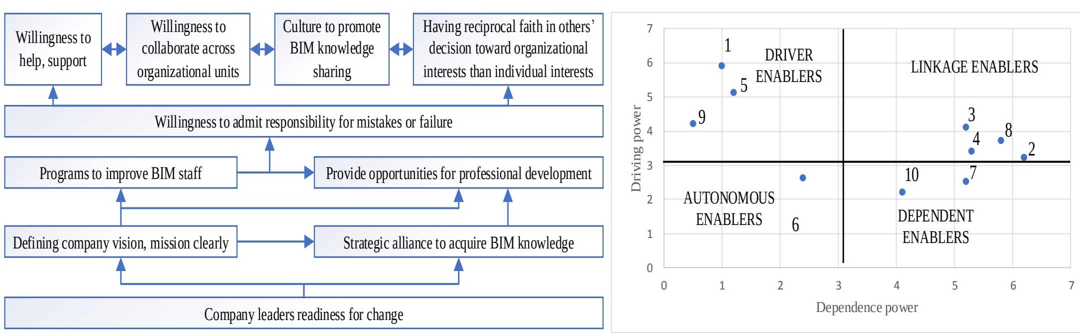

Figure 2. ISM model formulation and cluster of KEFBIs in large contractors.

From the driving-dependence power diagram, only I2 is identified autonomous, which are weak drivers, weak dependent, and relatively disconnected from the system. I2 and C4 are weak drivers, but are strongly dependent on the others. It indicates that two KEFBIs require all the others during BIM implementation to reduce the effect of these KEFBIs. C2, T5, C3, and SL2 have strong drive power as well as strong dependence power. Thus, if these KEFBIs have any change, it will affect others and themselves. The fourth cluster in the diagram includes SL9, SL11, and SL3, having strong driving power but weak dependence. These KEFBIs help achieve others, which appears at the top of ISM. Thus, management should facilitate these KEFBIs for successful BIM implementation in their organizations.

6 CONCLUSIONS

This paper presents 52 KEFBIs, the factor means and rankings of which are in conformity with different sizes of contractors. ISM fuzzy MICMAC analysis was used to provide accurate analysis, regarding the driving and dependence power of KEFBIs. The results can help contractors implement BIM more efficiently. Moreover, they can plan and allocate their resources optimally. This research only consists of country-related findings; the KEFBIs are identified for contractors in Vietnam. Without additional data collection, it cannot automatically be used in other countries and for other kinds of enterprises. Further studies should re-examine the results of this study in other countries and for other kinds of enterprises.

References

Arayici, Y., Coates, P., Koskela, L., Mike K., Usher C., and O'Reilly K., Building Information Modeling adoption and implementation for architectural practices, *Structural Survey*, Emerald, 29(1), 7-25, 2011.

Attri, R., Dev, N., and Sharma, V., Interpretive Structural Modelling (ISM) approach: An Overview, *Research Journal of Management Sciences*, 2(2), 3–8, 2013.

Bixler, C. H., Applying the Four Pillars of Knowledge Management, *KM World*, 11(1), 10-20, 2002.

Bryde, D., Broquetas, M., and Volm, J. M., The Project Benefits of Building Information Modeling (BIM), *International Journal of Project Management*, 31(7), 971–980, 2013.

Dang, N. C., Long L. H., and Kim, S. Y., Impact of Knowledge Enabling Factors on Organizational Effectiveness in Construction Companies, *JKM*, 22(4), 759-780, 2018.

Dossick, S., and Neff, G., Organizational Divisions in BIM-Enabled Commercial Construction, *Journal of Construction Engineering and Management*, 136(4), 459–467, 2010.

Flanagan, R., and Norman, G., *Risk Management And Construction*, Blackwell Science, Inc, 1993.

Gu, N., and London K., Understanding and facilitating BIM adoption in the AEC industry, *Automation in Construction*, 19 (8), 988-999, 2010.

Ho, C. T., The Relationship Between Knowledge Management Enablers and Performance, *Industrial Management and Data Systems*, 109(1), 98-117, 2009.

Homayouni, H., Neff, G., and Dossick, C., Theoretical Categories of Successful Collaboration and BIM Implementation within The AEC Industry, *Construction Research Congress*, 778-788, 2010.

Hung, Y., Huang, S., Lin, Q., and Tsai, M., Critical Factors in Adopting a Knowledge Management System for The Pharmaceutical Industry, *Industrial Management and Data Systems*, 105(2), 164-183, 2005.

Lee, H., and Choi, B., Knowledge Management Enablers, Processes, and Organizational Performance: An Integrative View and Empirical Examination, *JPIS*, 20(1), 179-228, 2003.

Lee, J. H., and Kim, Y. G., A Stage Model of Organizational Knowledge Management: A Latent Content Analysis, *Expert Systems with Applications*, 20, 299-311, 2001.

Lee, S., Kim, B. G., and Kim, H., An Integrated View of Knowledge Management for Performance, *Journal of Knowledge Management*, 16(2), 183-203, 2012.

Pan, S., and Scarbrough, H., A Socio-Technical View of Knowledge-Sharing at Buckman Laboratories, *Journal of Knowledge Management*, 2(1), 55-66, 1998.

Sin, C. H., Goh, G. G. G., and Eze, U. C., Knowledge Management Enablers Toward Successful New Product Development: A Case Study in A Semiconductor Manufacturing Firm, *JKMP*, 10(4), 16-32, 2009.

Stonehouse, G. H., and Pemberton, J. D., Learning and Knowledge Management in The Intelligent Organization, *Participation and Empowerment: An International Journal*, 7(5), 131-144, 1999.

Succar, B., and Mohamad, K., Macro-BIM Adoption: Conceptual Structures, *Automation in Construction*, 57, 64-79, 2015.

Teeragetgul, W., and Charoenngam, C., Factors Inducing Knowledge Creation: Empirical Evidence from Thai Construction Projects, *ECAM*, 13(6), 584-599, 2006.

Yeh, Y. J., Lai, S. Q., and Ho, C. T., Knowledge Management Enablers: A Case Study, *Industrial Management and Data Systems*, 106(6), 793-810, 2006.