Key Performance Indicator on Benefits of BSC-based BIM and Validation Methods

Chan-ho. Park [1], Jae-sang. Ahn [1], Dong-min Lee [1], Yu-na. Cha [1] and *Sang-yoon. Chin [2]

[1]*Department of u-City Design and Engineering Sungkyunkwan University,*
2066, Seobu-ro, Jangan-gu, Suwan, Korea
E-mail address:aqwert21@skku.edu

[2]*Professor, Department of u-City Design and Engineering Sungkyunkwan University*
2066, Seobu-ro, Jangan-gu, Suwan, Korea
E-mail address:schin@skku.edu

Key Performance Indicator on Benefits of BSC-based BIM and Validation Methods

ABSTRACT

As the building has recently become bigger, higher, and freeform, a technology called BIM(Building Information Modeling), which is a key technology that integrates construction and IT(Information Technology), has been rapidly introduced and expanded. Because BIM technology offers various benefits, countries that introduced BIM early has been actively promoted. However, misperceptions of BIM are prevalent in countries such as South Korea that have adopted it relatively late, with lack of awareness of its fundamental purposes. Under these circumstances, transparent and quantitative performance assessment needs to be executed in order to eliminate the misperceptions, and to explain and revitalize the BIM introduction. These quantitative performance measure KPI (Key Performance Indicators) to be measured should be prioritized.

As derive performance indicators in terms of the four types (financial, customer, internal processes, learning and growth), and performance management systems, Uses the BSC to seek a balance between short-term financial goals, values and the value of long-term goals.

Uses the BSC(Balanced Scorecards) to derive performance indicators in terms of the four types (financial, customer, internal processes, learning and growth), and performance management systems, seeking a balance between the value of short-term financial objectives and the value of long-term objectives. Through this, the KPI (Key Performance Indicators) which is used for measuring the effect of the BIM will be generated and also the method that can determine whether the generated KPI figures are objectively inter-connected will be suggested as well.

KEYWORDS

BIM, BSC, KPI, Principal Component Analysis, Varimax, Cronbach's a, Correlation analysis, LISREL

INTRODUCTION

As the architecture has recently become bigger, higher, and less structured, a technology called BIM(Building Information Modeling), which is a key technology that integrates construction and IT, has been rapidly introduced and expanded. In addition, the construction industry officials have actively promoted introduction of BIM technology, because it provides various benefits such as improvement of design productivity, visualization of information, minimization of design changes, review of construction and process management [10].

Such BIM technology is characterized by a step-by-step development, as shown in Figure 1. Unlike other countries that introduced BIM early (process-based BIM or collaborative BIM stage), there are different levels of development in countries such as South Korea (function-based BIM stage) that introduced BIM relatively late [11].

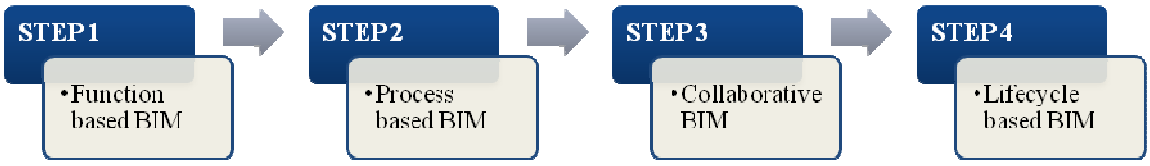

Figure 1-4 Stage Development Model of BIM[2]

In the current domestic (Korean) construction industry, BIM is not readily accepted, except for academic sectors, even though the advantages of BIM paradigms are well-received [9]. It is probably because misperceptions of BIM are prevalent, due to distortion of construction information by excessively focusing on the visual results, and the belief that BIM doesn't offer continuity and consistency of information, unlike its fundamental purposes. Unless such misperceptions are eliminated, Korea will stay on the function-based BIM stage without any development.

It is necessary to develop objective major performance indicators by priority that can measure the performances and can be compared to each other. Everyone knows that it is impossible to accomplish the goal with subjective or irrational standards. In order to set-up the objectified standard, the effort to change the qualitative standards into quantitative standards is realized through BSC.

Accordingly, this research aims to suggest a method to test the validity of generated indicators by using BSC for the generation of major performance indicators to measure the performance of the effect of BIM.

Method

1. Research Scope and Method

This study is aimed at offering a KPI that affects the BSC-based BIM introduction benefits and the validation methods. Therefore, it will establish the construction industry's BSC target (performance areas), which will allow for assessment and comparison of the industry performances after defining the BSC and analyzing its configuration system. Based on this, modified and supplemented in accordance with the characteristics of the BIM process. It will become a basis for producing a KPI of BIM introduction benefits by examining the related studies involving BIM introduction benefits, and combining the components of BIM utilizations at each construction stage with the construction industry's BSC target. Then a validation method for judging the suitability of key performance components will be presented. The method of this study is shown in Figure 2.

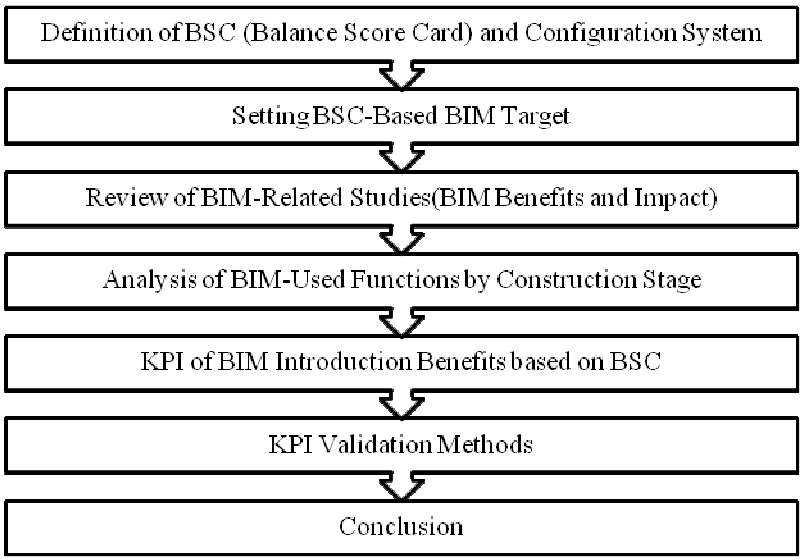

Figure 2-Main process in this paper

2. Definition of BSC (Balance Score Card) and Configuration System

2.1 Definition of BSC(Balance Score Card)

It is a frame that efficiently manages corporate performance, based on its vision, strategies, perspectives and KPI. BSC is a system that allows the management to promptly review the corporate

health by clearly integrating the major business performances into a few manageable KPIs. In addition, BSC is a balanced performance assessment record that comprehensively evaluates the corporate performance through Financial Perspective, Customer Perspective, Internal Business Perspective, and Learning and Growth Perspective. It not only evaluates the current corporate situations, but predicts its future, playing an important role in establishing a business strategy [6].

2.2 BSC Configuration System

The components of BSC can be summarized as follows: Vision, strategy, key success factors, KPI, cause and effect, goals, and feedback, each of which are correlated, rather than acting separately [7].

3. Setting BSC Target of Construction Industry [8]

The main purpose of precedent studies is development of common indicators that allow for assessment and comparison of construction firms' performances and analysis of quantitative characteristics of the indicators and their correlations. The performance assessment framework is used on the basis of four perspectives of BSC (Balance Score Card) model. The BSC target of construction firms was established (setting performance areas) through analysis of their strategies and goals, and the BSC-based construction firms' performance areas are shown in Table 1. Based on table 1, BIM based process performance areas are established after adjusting to BIM based process character(Table 2).

Table 1-BSC-based construction firm performance area[8]

BSC 4perspectives	12 performance areas of construction firm
A. Financial	1. Profitability
	2. Growth
	3. Stability
B. Customer	4. External customer satisfaction
	5. Internal customer satisfaction
	6. Market share
C. Internal processes	7. Investment in research and development
	8. Technical skills
	9. Efficiency
D. Learning and Growth	10. Manpower
	11. Organizational capabilities
	12. Information

Table 2-BIM based process performance areas

BSC 4perspectives	10 performance areas of BIM based process
A. Financial	1. Profitability
	2. Growth
B. Customer	3. External customer satisfaction
	4. Internal customer satisfaction
C. Internal processes	5. Utilization effect level at Planning Stage
	6. Utilization effect level at Designing Stage
	7. Utilization effect level at Construction Stage
	8. Utilization effect level at Maintenance Stage
D. Learning and Growth	9. Organizational capabilities
	10. Education

4. Review of BIM-Related Studies

The precedent studies related to benefits of BIM introduction and the effects are illustrated in Table 3. Some analyzed the BIM introduction effects only with regards to particular tasks, such as analysis of construction (Park Chan-Shik and Park Hee-Tak. 2010; Lee Seung – Il. et al. 2010) and analysis of contractor demands at the design stage (Aslani, P. et al. 2009), while others were limited to only presenting the benefits of BIM (Zuppa et al. 2010) [3]. Thus, there are practically no studies on BIM benefits and effects with regards to the entire process of the construction industry.

Table 3- Studies related to benefits of BIM introduction and the effects[3][2]

Classification	Main Content
Benefits of BIM introduction and the effects	Analysis the BIM introduction of constructability business, present the expected effects (Park Chan-shik. et al. 2010)
	Analysis constructability by the BIM introduction of frame construction, present the expected effects(Lee Seung – Il. et al. 2010)
	By applying BIM in the design phase of the requirements of the contractor to work efficiently(Aslani, P. et al. 2009)
	Construction sites perform a step-by-step / direction of building management model through the analysis of subject-specific requirements presented (Jeon young-ung. et al. 2010)
	Distinguishing as the respondents' age, education, role definition and impact of BIM. (Zuppa et al. 2010)

5. Analysis of BIM-Used Functions by Construction Stage

In order to produce a KPI through analysis of BIM introduction benefits and BIM based process performance areas set according to construction process(Table 2), which will be compatible with each other, BIM-used functions should be analyzed first. Table 4 shows the classification of BIM functions by the construction stage for development of performance indicator through a review of related studies and research into existing BIM systems.

Table 4- BIM functions by the construction stage[2][5]

Step	BIM function
Planning stage	- Data collection - Management of demands from contractor - Space planning - Data and model extraction
Designing stage	- Design-related meetings - Creation of designing guideline - Management of design interface - Design book /drawing - Design VE - Quantity surveying and quote - Structural designing and analysis - Energy and environmental analysis
Construction stage	- Construction details - Materials management - Process / safety / quality management - Review of design or construction changes - Construction VE - Interference check by the construction type/ area
Maintenance stage	- Review of test operation - Establishment of operating manual - Establishment of maintenance system

	- Repairs

6. KPI of BIM Introduction Benefits based on BSC

Because BIM process involves both tangible benefits that can be objectively measured and quantified, and intangible benefits, such as improvement of quality, design capabilities, services, and work environment, which are not easily measured and quantified, both tangible and intangible benefits should be considered for decision-making as to informalization through BIM benefit analysis. In addition, since the correlations among project performances following BIM utilization are difficult to be identified through conventional financial indicators, such as ROI and EPS, a new analysis method that can comprehensively identify the corporate project improvement and performances should be used. In doing so, benefits obtained through BIM utilization can be represented as currency units using an indicator, and the method is called BSC [14]. Therefore, establishment of KPI of BIM introduction benefits based on BSC is indeed valid. The key model was established, based on compatibility among the previously-established BIM based process performance areas(Table 2)as shown in Table 5, and BIM utilizations(Table 4) by the construction stage.

Table 5- BIM utilizations by the construction stage[13][14]

Perspective	Key Success Factor		KPI (Key Performance Indicator)
A. Financial	A.a	Profitability	A.a.1 Did BIM utilization provide financial benefits beyond the investment costs?
	A.b	Growth Potential	A.b.1 Did application of BIM provide the benefit of creating future values?
B. Customers	B.a	External Customer Satisfaction Level	B.a.1 Working-level meeting satisfaction level at the BIM-used planning stage? B.a.2 Working-level meeting satisfaction level at the BIM-used designing stage? B.a.3 Working-level meeting satisfaction level at the BIM-used construction stage? B.a.4 Working-level meeting satisfaction level at the BIM-used maintenance stage?
	B.b	Internal Customer Satisfaction Level	B.b.1 BIM-used work satisfaction level at the planning stage? B.b.2 BIM-used work satisfaction level at the designing stage? B.b.3 BIM-used work satisfaction level at the construction stage? B.b.4 BIM-used work satisfaction level at the maintenance stage?
C. Process Utilization	C.a	Utilization Level at Planning Stage	C.a.1 BIM utilization effect level for data collection? C.a.2 BIM utilization effect level for management of demands from contractor? C.a.3 BIM utilization effect level for space planning? C.a.4 BIM utilization effect level for data and model extraction?
	C.b	Utilization Level at Designing Stage	C.b.1 BIM utilization effect level for design-related meetings? C.b.2 BIM utilization effect level for creation of designing guideline? C.b.3 BIM utilization effect level for management of design interface? C.b.4 BIM utilization effect level for review of design book /drawing?

			C.b.5 BIM utilization effect level for design VE? C.b.6 BIM utilization effect level for quantity surveying and quote? C.b.7 BIM utilization effect level for structural designing and analysis? C.b.8 BIM utilization effect level for energy and environmental analysis?
	C.c	Utilization Level at Construction Stage	C.c.1 BIM utilization effect level for review of construction details? C.c.2 BIM utilization effect level for review of materials management? C.c.3 BIM utilization effect level for process / safety / quality management? C.c.4 BIM utilization effect level for review of design or construction changes? C.c.5 BIM utilization effect level for construction VE? C.c.6 BIM utilization effect level for interference check by the construction type/ area?
	C.d	Maintenance Utilization	C.d.1 BIM utilization effect level for review of test operation? C.d.2 BIM utilization effect level for establishment of operating manual? C.d.3 BIM utilization effect level for establishment of maintenance system? C.d.4 BIM utilization effect level for repairs?
D. Learning and Growth	D.a	Organizational Capabilities	D.a.1 New workload satisfaction level after BIM introduction? D.b.2 Work performance satisfaction level regarding the BIM-based collaboration system? D.b.3 Work-sharing satisfaction level after BIM introduction?
	D.b	Education	D.b.1 Do you have a regular BIM project of the education benefits?

The four categories suggested by this study are as follows. First, KPI of introduction benefits based on financial factors of BIM-based project execution. Second, KPI of BIM introduction benefits in terms of customer satisfaction level following BIM introduction (customer perspective). Third, KPI of BIM introduction benefits through BIM utilizations effect by the construction stage (process perspective). Fourth, KPI of BIM introduction benefits as to internal organizational capabilities and educational level (learning and growth perspective).

7. KPI Validation Methods

Validation is required in order to determine whether the produced KPI is objective enough to be used as quantitative and qualitative indicator. Using the Likert five-point scale, through fill out the questionnaire, Conducted a sample survey by the construction company about the derived KPI(Table 5). This study suggests a method shown in Figure 3, and it is as follows.

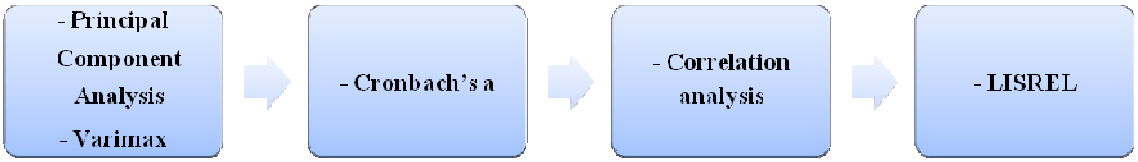

Figure 3- Step KPI Validation Methods suggestion

1. Using the Varimax method to prove that variables are interdependent as a factor analysis method and analyzing the major components[15].
2. Calculation of Cronbach's alpha values that evaluate the internal concordance to verify the reliability [15].
3. Analysis of correlations by the factor, based on the produced results through factor analysis[15].
4. Confirmatory factor analysis using LISREL, in order to revalidate the measured items of each category established through factor and reliability analysis[1].

8. Conclusions

This study was intended to explain the necessity of BIM introduction benefits and revitalize it by producing a KPI for performance measurement of BIM introduction benefits. Because BIM processes involve both tangible benefits that can be objectively measured and quantified, and intangible benefits that are not easily done so, both benefits should be considered for decision-making as to informalization through BIM benefit analysis. In doing so, BSC method can be effectively used. Based on the method, a KPI of BIM introduction benefits was created as follows.

First of all, BSC target of construction firms was established through analysis of strategies and goals of construction firms, based on four perspectives of BSC (Balance Score Card) model [Table 1]. Second, BIM-used functions were analyzed at each construction stage of planning, designing, construction, and maintenance, in order to produce a relevant KPI, based on the established performance areas [Table 3]. Finally, a model that presents a KPI relevant to BSC-based performance areas produced and analysis of BIM introduction benefits and BIM-used functions was created, which are all compatible with each other [Table 4].

Since validation is essential for objective assessment of indicators, a validation method based on Varimax method, calculation of Cronbach's alpha values, analysis of correlations by the factor, and LISREL was presented.

It is highly likely that the KPI created in accordance with the process presented by this study will become the key point in developing tools for performance measurement with objective quantitative and qualitative assessment, and will greatly contribute to proving the necessity of BIM introduction and its revitalization.

Acknowledgement

This work is financially supported by Korea Minister of Ministry of Land, Transport and Maritime Affairs(MLTM) as 「U-City Master and Doctor Course Grant Program」.

REFERENCES

[1] Byoung-ryeol Bae(2005). LISREL structural equation modeling. Cheong Ram Publishing Co.

[2] Chan-sik Park(2010). Improving Constructability Analysis Task by Applying BIM Technology. Korean Journal of Construction Engineering and Management

[3] Chi-joo Lee(2011). Derivation of High-Priority Items for BIM Adoption in CM Service – CM Service for High Rise Building-. Journal of ARCHITECTURAL INSTITUTE OF KOREA

[4] CHUCK EASTMAN(2010). BIM Handbook. John Wiley & Sons, Inc

[5] DO-young Park(2010). A Study on Development of Supporting System for Pre-design Phase based on BIM. Journal of computational Structural Engineering Institute of Korea

[6] http://terms.naver.com/entry.nhn?cid=2053&docId=205&mobile&categoryId=2053

[7] Hui Gyeong Kim(2001). BSC practice manual. Sigma inside

[8] Il-han Yu(2006). Analysis of Quantified Characteristics of the Performance Indicators for Construction Companies. Korean Journal of Construction Engineering and Management

[9] Ju-sung LEE(2010). An Analysis about Factors affecting Inactiveness of BIM(Building Information Modeling) Introduction in the Construction. Korean Journal of Construction Engineering and Management

[10] Su-won Yoon(2009). A BIM Study in Construction Phase : D3 city Project. Journal of ARCHITECTURAL INSTITUTE OF KOREA

[11] Noo ri Choi(2009). Overview of BIM and Advice on Introduction to Local Construction Companies. Samsung SDS Journal of IT Services Vol.6 / No.2

[12] Seung-chan LEE(2005). Measure the effect of RTE-based digital enterprise management. IT Business journal

[13] Leen-seok Kang. Development of Performance Indicators for Construction IT Tool based on BSC. Journal of The Korean Society for Railway

[14] Mi-rim Song(2011) BSC Based Measurement of Satisfaction Degree For Based BIM Construction Projets . Korean Journal of Construction Engineering and Management

[15] Tae-yeon Won(2010). Statistical research and analysis(SPSS PASW STATISTICS 18.0). Hannarae Publishing Co.

[16] Young-woong Jeon. A Study on the Development of a Construction Field Management Model based on BIM. JOURNAL OF THE KOREA INSTITUTE OF BUILDING CONSTRUCTION