Original Article
ISSN (Online): 2454-1907

International Journal of Engineering Technologies and Management Research
September 2022 9(9), 67–79

THE IMPACT OF INTEGRATING BUILDING INFORMATION MODELING (BIM) TECHNOLOGY AND RE-ENGINEERING PROCESS IN CONSTRUCTION PROJECTS

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Received 11 August 2022
Accepted 11 September 2022
Published 26 September 2022

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DOI 10.29121/ijetmr.v9.i9.2022.1217

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

In general, the recent findings obtained in line with current construction industry conditions confirm the idea of evaluating the design before its actual implementation. Accordingly, the design needs to be examined and reviewed from various aspects before the implementation of the design in construction projects in order to eliminate the possible obstacles, problems and errors of the system. Traditional methods and techniques included multiple reviews and double-checking of maps. This method is time consuming compared to new methods and technologies, and the percentage of errors is high. Therefore, traditional methods should be replaced by more effective methods. One of the most effective advanced technologies in the world that has been faced with a great welcome around the world is Building Information Modeling (BIM). This method has significant organizational benefits and causes a systematic change in the organization. In this paper, we will examine the status of building information modeling in construction projects and organizational maturity.

Keywords: BIM, Re-Engineering, BIM Modeling, Construction Projects

1. INTRODUCTION

Considering the fact that the use of building information modeling technology has become increasingly popular around the world due to its significant advantages, it is necessary to better understand the capabilities and efficiency of this technology and the consequences of its application in construction projects. For this purpose, it is necessary to get acquainted with various types of modeling methods in the BIM system, integrated project delivery and evaluation indices. In this paper, we try to get acquainted with the concepts and a specific perspective of BIM in construction projects. Therefore, by identifying these factors and evaluating the indices correctly, we can begin the next step - implementation of the BIM – more confidently.

2. TYPES OF MODELING IN CONSTRUCTION PROJECTS

2.1. OBJECTS-BASED MODELING

In general, at the first stage of the BIM, presented in the Succar framework, companies develop single-discipline models in the design, construction, or operation phase of the project. For example, architectural models, engineering models, or prefabricated models are used in the early stages to prepare two-dimensional and three-dimensional documentations. The first stage in implementing BIM in prefabricated concrete structures is very similar to the method described above, and in practice this means that the BIM software is implemented in one of the project phases. This is usually done either in bidding, design, or construction phases. In general, at all phases, the model is produced by the design department of the prefabricated concrete factory. In fact, BIM refers to a set of technologies and solutions aiming to enhance inter-organizational collaboration in the construction industry, that will enhance productivity whilst improving design, construction, and maintenance practices Miettinen and Paavola (2014). 3D modelling began in the early 1970s based on CAD technologies developed in diverse industries Eastman et al. (2011). As a result, the construction industry applied 2D design initially for utilizing CAD Eastman et al. (2011), Volk et al. (2014).

Generally, object-based modeling is a standardized set of symptoms and methods for arranging them in the form of a model of an object-oriented software design or system design. Some organizations use them extensively in combination with a software development methodology to get from a basic profile to an implementation design and link that design with the entire team of developers, because it is a real modeling language, and it is a bit more abstract than the code. The application of the models encourages a generation of shared views that may prevent problems later on. Sometimes modeling software tools are used to build these models that may have the capability to automatically convert them to codes. In the event of design changes BIM tools can integrate and systematise changes with the design principles,

intent and design 'layers' for the facility/project Autodesk (2002).

The early stages of the BIM include the initial input data and the initial three-dimensional models without any parametric modifications Succar (2010).

Initial data usually includes a list of materials, two- and three-dimensional maps, as well as a sequence of the parts installation.

In general, the idea of parametric elements and objects is an important and significant concept in better understanding the modeling of building information and their differences with three-dimensional objects in the traditional system; these differences are as follows:

- Objects have geometric definitions and interconnect and integrated information and rules.
- The geometry of these objects is defined unambiguously without additional information.
- Parametric rules apply automatically when placing objects in the model.
- Objects can be defined with different degrees of compositions and an object can be defined along with various layers and components within it.
- In the event of a conflict, the present incompatibility is detected by the parametric rules.

- Objects have the ability that some attributes and characteristics to be allocated to them and an output to be get from them.

According to Succar, the process in the first stage of BIM is the same as the Pre-BIM stage. Typically, the exchange of information between different parts of the project is unidirectional indicating that although sometimes three-dimensional maps are used instead of two-dimensional maps, various parts of prefabricated concrete factories continue to use maps to connect and cooperate with each other; for example, when implementing reinforcement in molds or installing precast concrete components in place.

Since usually only minor changes occur in the first stage of the BIM implementation, the contractual relationships and criteria, risk allocation and organizational behaviour are usually the same as the Pre-BIM stage. However, in the object-based modeling, it is possible to run faster the different stages and phases of the project. And when the project is still in the implementation phase, usually the design and construction phases are done simultaneously Succar et al. (2012).

In Figure 1, the linear representation of the various phases of the project life cycle in the first step of the BIM is shown so that there is no overlapping between different stages. After implementing BIM in one of the departments of a prefabricated concrete factory, it is clear that the benefits of that department will transfer modeling-based activities to other departments of the company.

Figure 1

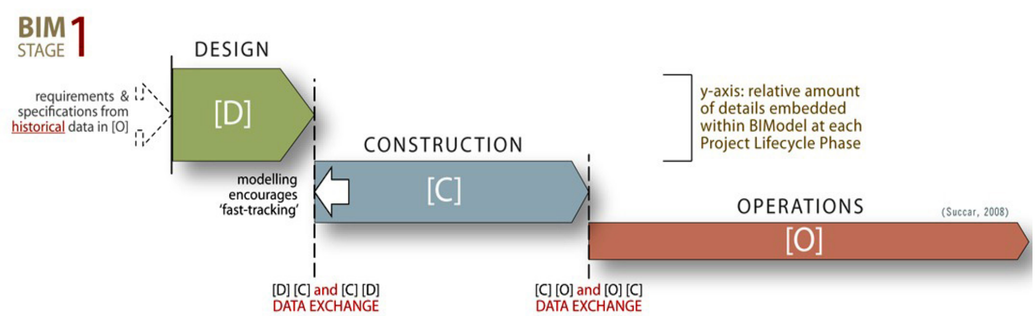

Figure 1 The Various Phases of the Project Life Cycle in the First Stage of the BIM

According to Venkatraman, from the perspective of re-engineering, at the initial stage of BIM implementation, companies implement information technology applications, and it is necessary to use BIM software with minimal change in the process.

According to Hannus, in the first stage (level) of implementing BIM, IT solutions are separated from specific organizational goals and are used for internal organizational goals Hannus (1994).

BIM and re-engineering theories support each other and have almost the same function as the first stage of the implementation of BIM.

2.2. MODELING BASED ON COMMUNICATION AND COLLABORATION

When companies used the single-line modeling method to implement the first BIM stage, they were also able to collaborate with other active team members in the second stage of implementation, so that this communication and collaboration method was made possible with the help of various technologies.

After the first stage of the BIM implementation, the active department at the structural prefabricated concrete manufacturing plant used BIM software as part of its work process, and in the second stage it began to establish active communication and collaboration between the various departments inside the company.

Although sometimes in the early stages of the work the design department uses an object-based approach, the perspective of the internal management of the organization can focus on an approach based on collaboration and establishing a link between various departments.

According to Succar, a model based on collaboration and communication may be used between two different phases in the project life cycle (in the second stage of BIM).

This method may include both exchange models that interchange between different teams, and non-specialized formats. In the case of prefabricated concrete manufacturers, this means that the models developed by the design department will be shared between the executive teams. The collaboration between design and implementation departments often requires the presence of general design models, while the executive department needs information about the entire project. In the meantime, if the design department collaborates with other departments, the partial modeling of the project (related to particular parts of the project) will usually be preferred to overall models. This is true if various departments of the project work on parts of the project (not the entire project). At the same time, in the initial stages of work, the need for partial information and data will be preferable over general data.

Although the collaboration and communication between BIM users in a project may not be simultaneous, the Pre-BIM stage boundaries and limitations that cause separation of criteria will lead to a gradual fading of the project's lifecycle phases.

In Figure 2, the linear representation of various phases of the project life cycle is shown in the second stage of the BIM. As you can see, unlike the first stage of implementing the BIM, there is overlap in various phases of the project. For manufacturers of prefabricated concrete, the existence of this overlap means that the second stage of implementing the BIM requires the definition of and policies on how the communication and collaboration between different project teams (not just modeling) should be done. At the same time, prefabricated concrete manufacturers must, at their work processes, re-engineer their work stages in accordance with the model-based workflow in order to benefit from all the benefits and advantages of implementing the BIM.

Figure 2

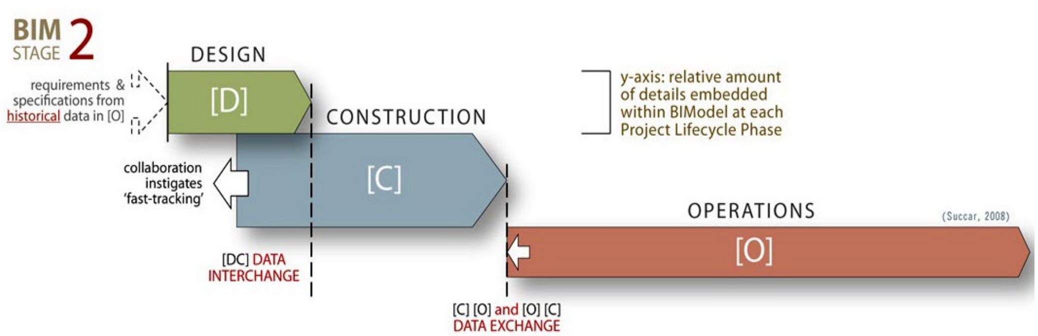

Figure 2 The Various Stages of the Life Cycle of the Project in the Second Stage of the BIM

It should be noted that applying BIM tools for existing buildings, offers a range of alternative potential benefits for the built environment Kensek and Noble (2014), includes of as-built renders Pătrăucean et al. (2015), Cho et al. (2015), maintenance Motawa and Almarshad (2013), control of quality Boukamp and Akinci (2007), retrofitting Mill et al. (2014), Woo and Menassa (2014), Evaluation and monitoring Eastman et al. (2011), Becerik-Gerber et al. (2011), Arayici (2008), tracking warranty and service information Singh et al. (2011), Eastman et al. (2003).

According to Venkatrama, from the perspective of re-engineering, the second stage of BIM implementation suggests a more systematic effort to implement information technology at different stages of the work. Therefore, in the second stage of implementation, the interdependence between technical and commercial sectors is quite evident, because none of them alone is enough and the advantages of implementing information technology will not be fully reflected.

Therefore, according to Hannus, in the second stage of implementing the BIM, the integration of information technology inside the company is a sound and principled method for the implementation of information technology regardless of the structure and the existing stages of work Arayici (2008).

Meanwhile, before starting the stages of the actual implementation of BIM, prefabricated concrete manufacturers pay attention to the fact that when integrating BIM software as part of the company's internal workflow and activities, which steps should be changed in order to achieve an appropriate level of productivity.

2.3. NETWORK-BASED MODELING

In the third stage of the BIM, using various technologies, databases or software services, models containing integration information are prepared and shared and maintained at all stages of the project's useful life.

The prerequisite for entering this stage is the evolution of software and networking technologies so that they can share existing information. This means that at this stage of the implementation of BIM, prefabricated concrete manufacturers will prepare, share, and maintain integrated models in different parts of the project and internal departments.

In the third stage of the BIM, the models become multi-dimensional models (nD models) so that complex analysis can be made at the early stages of design and construction.

Accordingly, the use of multi-dimensional models (for example, the fourth and fifth dimensions of BIM which are related to time and cost, respectively), unlike the use of the features of traditional objects in the design, create the basis for lean manufacturing, green systems (environment friendly) as well as estimating the cost of the project in its useful life. Concerning the BIM implementation stage, this means that prefabricated concrete manufacturers should pay attention to various factors that each part of the project needs them, and they should consider them in their calculations.

According to Succar, the simultaneous exchange of the model and existing documentary data allows the various stages of the project life cycle to overlap, which will ultimately become a single-stage process (the figure below).

Network-based integration causes the various stages of construction to be done simultaneously, especially when all project activities are integrated and all aspects of design, construction, and operation are planned simultaneously, so that the value of the target functions is maximized.

According to Succar, the implementation of the third stage of BIM requires revision of contractual relationships, risk allocation models and workflow trends. The third stage of BIM implementation focuses on policies, especially from a network perspective. In the meantime, changes must be made to some existing stages.

From Eastman's point of view, there are four methods for exchanging model information between two software applications Arayici (2008):

- Direct links between BIM special tools
- Exclusive file format exchange (DXF files)
- General-level transfer formats (Revit Architecture, Bentley Architecture, ArchiCAD, etc.)
- File formats based on XML

Table 1

Table 1 Types of Information Exchange Formats in AEC

Image formats (Raster)	Description
JPG, GIF, TIF, BMP, PIC, PNG, RAW, TGA, RLE	These Formats are Different in Terms of Compression and the Number of Possible Colours Per Pixel.
two-dimensional formats (vectors)	Description
DXF, DWG, AI, CGM, EMF, IGS, WMF, DGN	Vector Formats are Different in Terms of Compression, Line Thickness, Colour, etc.
three-dimensional shape and plane formats	Description
3DS, WRL, STL, IGS, SAT, DXF, DWG, OBJ, DGN, PDF(3D), XGL, EWF, U3D, IPT, PTS	Three-Dimensional Shape and Plane Formats are Different in Terms of the Type of Planes, How to Display the Edges, and the Properties of the Materials (Colour, Texture, Etc.).
three-dimensional transmission and exchange formats	Description
STP, EXP, CIS/2	It Is Related to Two-Dimensional and Three-Dimensional Objects and Usually Contains the Characteristics of the Subject and their Relationships.
Game formats	Description
RWQ, X, GOF, FACT	The Game File Formats are Varied Based on the Type of Planes, their Hierarchical Structure, Types of Material Properties, Textures, Animations, and So on.
GIS formats	Description
SHP, SHX, DBF, DEM, NED	Geographic Information System Formats
XML formats	Description
AexXML, Obix, AEX, bcXML, AGCxml, IFCxml	The Transfer of Building Information Varies Depending on the Exchanged Information and the Workflow.

Figure 3

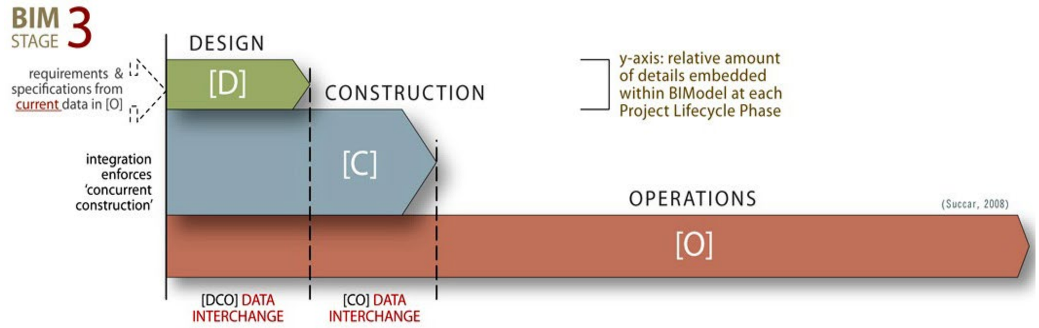

Figure 3 The Various Stages of the Project Life Cycle in the Third Stage of the BIM

According to Succar et al. (2012), the previous stages of reengineering and BIM are more focused on creating a transformation in the working process in individual company or organization. But the third stage of re-engineering involves focusing on redesigning the network and improving its performance through the implementation of information technology capabilities.

From Hannus's point of view, the starting point for this re-engineering stage is to redesign the existing core processes and structures that may be done within the company or through collaboration with other companies and organizations. In terms of re-engineering, in the third stage of BIM implementation, prefabricated concrete manufacturers need to connect and collaborate with other parts of the project in order to start the re-engineering phase. Finally, the growth and advancement of technologies, business processes and policies will facilitate the executive process of the project implementation.

3. INTEGRATED PROJECT DELIVERY

From Succar's perspective, Integrated Project Delivery (IPD) is a good tool for displaying the long-term vision of BIM as a mix of different technologies, business processes and policies.

In short, the IPD can be defined as a goal of the implementation of the BIM, which begins with the Pre-BIM stage and continues until the end of the three implementation stages.

In prefabricated concrete manufacturing companies, the latest stage of BIM implementation can be considered as the company's future goal.

In view of reengineering, the final stage of BIM implementation reflects the redefinition of the company's ideas and goals. Both of these factors must be judged on the basis of information technology capabilities.

4. EVALUATION INDICES

Eastman et al. (2011) suggests that when activating information technology, the first thing that any company should do is to identify and determine the extent and level of transformation at which the organization's interests are met.

On the other hand, according to Coates, before the actual implementation of reengineering and the development of a strategy approved for it is initiated, it is necessary for companies to make decisions about identifying the goals and characteristics of the implementation. Based on the above findings, it is inevitable that some evaluations should be undertaken prior to implementing the BIM. In this regard, the projection of potential costs, the need for labour and the extent of changes should be considered.

Along with considering the applicable indices, it is obvious that all executive aspects of an implementation cannot be analysed with just a single index. Therefore, in order to fully assess the existing gap between the current situation and the company's future goals, it is necessary to use multiple evaluation indices.

Suitable and consistent indices for prefabricated concrete industry are listed in the BIM implementation framework provided by Succar.

Succar has identified three parts for BIM:

- Technology
- Process
- Policies
- Meanwhile, he has defined three stages in implementing the BIM:
- Object-based modeling
- Collaboration-based modeling
- Network-based modeling

When these two (parts and stages) are combined, three valid indices will be obtained that can be used for analysis. The first analytical index is derived from the combination of the BIM technology aspect (one of the BIM parts) and the object-based modeling aspect (one of the BIM implementations stages).

In the object-based modeling stage, data is being used by teams and personnel within the company. In the case of prefabricated concrete manufacturing companies, this means that the design department uses the BIM inside the company, but the design that they use is based on maps. In addition, this means that in BIM Fields, which is related to different parts of BIM, any process or network is not yet defined, so the only solution is the use of technology (BIM software). In Figure 4, the first index used in the analyses is shown.

Figure 4

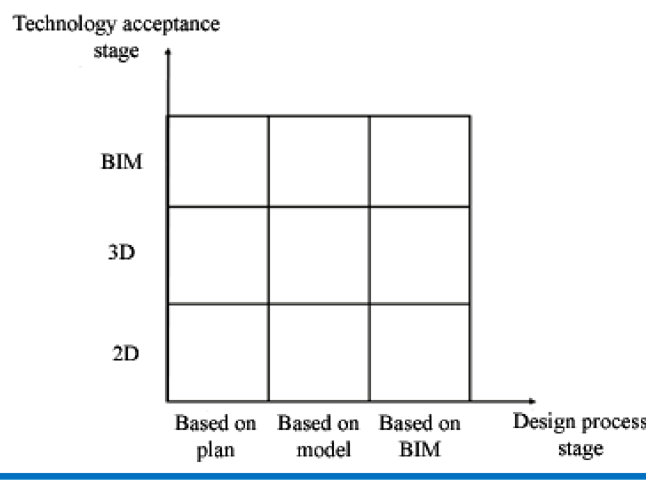

Figure 4 Main Processes Index. In this Index, the X-Axis Represents the Design Process Stages (Map-Based, Model-Based, BIM-Based), and the Y-Axis Represents the Adoption Stages of the Technology (two-dimensional, three-dimensional, or BIM)

The X-axis represents the design process stages in a company. In the map-based stage, the design is done by the two-dimensional AutoCAD software (CAD 2D), and the design process and the relationship between different parts of the project depends entirely on the maps. In the model-based stage, the design is done by three-dimensional AutoCAD software (CAD 3D) and BIM software, and the design process and the relationship between the different parts of the project will continue to depend on the maps. Finally, in the BIM-based stage, design is done by the BIM software, and the design process and the relationship between the different parts of the project depend entirely on the model information and data that is being prepared using the Building Information Model. The Y-axis in the above figure represents the technology adoption stage in the company. In the two-dimensional (2D) stage, companies' business processes and stages are based on maps and two-dimensional details, contracts and other paper documents that influence decision making. In the three-dimensional (3D) stage, companies' business processes and stages are significantly based on two-dimensional methods, but in some departments of the company, pre-existing 3D models are also used. In the BIM stage, companies' business processes and stages are redesigned in a way that enables them to effectively use the data and information available in the building information model.

The second index used in the analysis is the result of a combination of different parts of BIM, called BIM Fields, and a collaborative model. For Succar, in a stage in which the model is collaborative and communication-based, different teams and units of the organization cooperate and collaborate. In the case of prefabricated concrete manufacturers, this has two implications. First, a combination of different methods of cooperation may be created between the various units of the organization and other components of the team, such as architects and engineers. Second, a specific communication and collaboration may be created between the design unit and the executive (construction) unit, which can include collaboration and communication in the fields of logistics, production, and installation. Third, it is possible to communicate and collaborate between the project design unit and the project owner. In this analytical method, most attention is paid to inter-organizational collaboration and communication between the design unit and the executive (construction) unit. At BIM Fields, technology is currently being used and the development of process and stages have been started, but the network has not yet been created. The second analytical index is shown in the figure below.

Figure 5

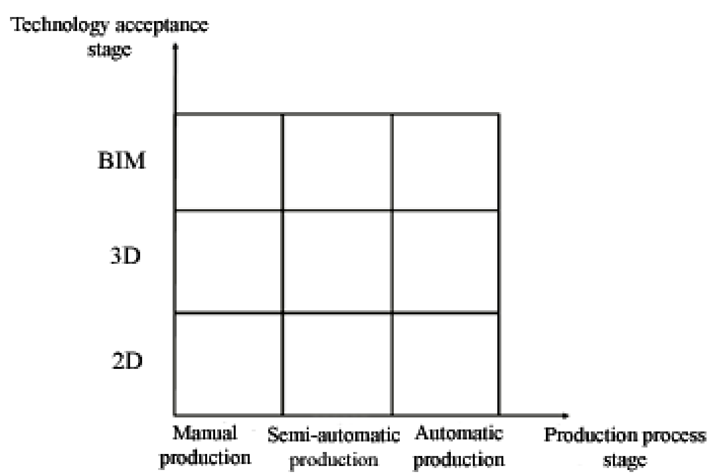

Figure 5 The indices of process and stages of production. In this index, the x-axis represents the production process (manual production, semi-automatic production, or fully automated production), and the y-axis represents the technology adoption stage (two-dimensional, three-dimensional, or BIM).

In the Figure 5, the x-axis represents the production procedure in a prefabricated concrete factory. In the manual production method, the production stage of prefabricated elements is done manually and according to the plans sent from the design department. In the semi-automatic production stage, part of the production of prefabricated elements is done manually and the other part is automatically done. In this case, the automatic part is done using 3D maps and BIM. For example, reinforcements, meshes and armature racks can be manufactured using special equipment and machinery and be assembled just before concrete casting. In the automatic production stage, the production of precast elements is carried out using sophisticated equipment and machinery. In this method, there is no need for skilled labour because the automatic equipment controls the production of precast concrete components. The y-axis in this figure is similar to the one shown above.

The third index used in the analysis is the result of a combination of different parts of BIM, called BIM Fields, and a network-based integration approach. For Succar, in a stage in which the model is network-based, different teams and units create, share, and maintain building information models. Technologies are used in BIM Fields, but the right policies such as setting of conventions and regulations have not yet been developed at this level. The third index is shown in the figure below.

Figure 6

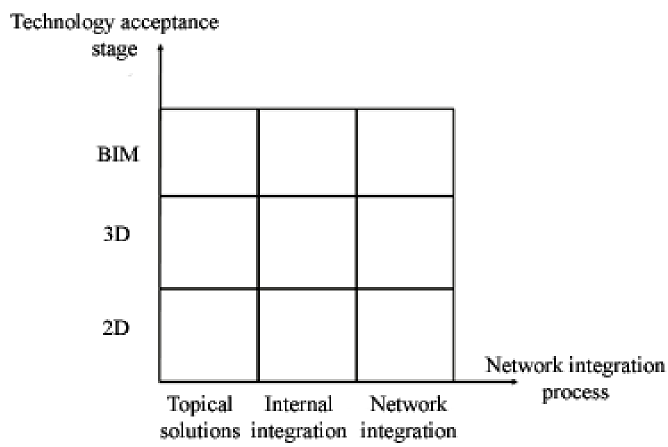

Figure 6 Network Integrity Index. In this index, the x-axis represents the network integration stage (local solutions, internal solutions, network integrity), and the y-axis represents the technology adoption stage (two-dimensional, three-dimensional, or BIM)

In the Figure 6, the x-axis represents the stage of network integration. In local solutions, networking and data transferring are limited to some departments of the company. For example, in a design department, information and data are effectively shared internally and are not transmitted outside the company. In the internal integration stage, networking and data sharing are carried out internally and no information is transmitted outside the company. In the network integration stage, networking and data sharing are conducted throughout the company's information chain, which in turn includes different partners and departments of the company. The y-axis in this figure is similar to the one shown above.

Based on these three indices, it is possible to evaluate the current activities of the company and at the same time, it will be possible to review future objectives and estimate the implementation. An example is shown in the figure below, which illustrates how these three indices can be used when assessing the impact of the implementation of the BIM on the company. When using these three indices, the company marks each index by two points, which later indicates the current status (red dot) and future situation (blue dot). In addition, with the help of this information, it will be possible to display gaps in the implementation (gray arrow) as well as how to begin and run the implementation of BIM (two gray dashed lines).

Figure 7

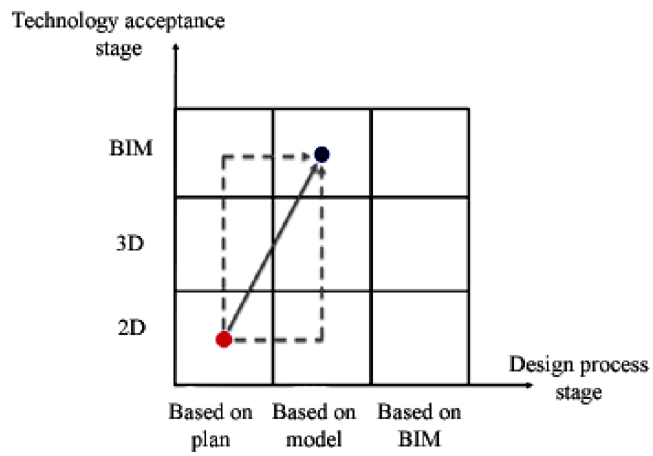

Figure 7 An example of how to use the three evaluation indices. The red dot indicates the current status of the company. The blue dot represents the company's future goals. The gray arrow represents the gap between the existing conditions and the company's future goals, which can be used to make decisions about the change during the implementation of the BIM. The two gray dashed lines represent the alternative ways used to implement the BIM.

In general, the first index indicates the gap between the extent of resources and actions required in the first stage of the implementation of the BIM when the BIM is still implemented in part (for example, in the design department) at the company. The second index illustrates the gap between the extent of resources and actions required in the second stage of the BIM implementation, when the BIM has been implemented in several parts of the company and information about the building information model is easily shared between other departments of the company.

The third index indicates the gap between the extent of resources and actions required in the third stage of the BIM implementation, when implementation of the BIM is started between two or more companies so that the information obtained from the model is without error and more efficient.

In general, this relative yet simple assessment method identifies three basic issues for companies that are in the BIM acceptance stage:

1) From the three existing BIMs, called BIM Fields, what is the position of the company?
2) What are the company's future goals and plans?
3) What is the gap between the two points?

The points that affect assessing the position of companies in the market are:

1) Position of competitors based on the three above-mentioned indices
2) Can a larger market share be obtained using BIM?
3) Are there new business opportunities in this new technology?

The evaluation of the three indices helps companies understand where and when major challenges arise during the implementation of the BIM.

This evaluation method provides a good starting point for development of a BIM implementation plan. However, the required resources, the extent of changes needed, etc. can be determined after the evaluation stage. In summary, as a result of the assessment stage, a clear blueprint of how to implement the BIM should be prepared, so that later on it can be used to define the planning method, required human resources and other resources needed for the successful implementation of BIM.

5. CONCLUSIONS

The use of information modeling technology has very significant effects on facilitating the project's implementation process, so that the possible duplications and errors in the implementation stage could be reduced by three-dimensional drawing of the design and assigning attributes to each one. This technology relies on three types of modeling techniques: object-based modeling, networking, and collaborative and communication-based modeling. In object-based modeling, companies develop single-discipline models in the design, construction, or operation phases of the project. In a network-based modeling approach, models containing integrated data are developed and shared through a variety of technologies, databases, or software services, and are maintained at all phases of the project's useful life. In collaborative and communication-based modeling, companies develop active collaborations and communications between various departments within the company. The result of this advanced modeling and integration will be the creation of an effective bridge between all the factors involved in the implementation of the project, including architectural, structural and facility engineers.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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