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An Investigation on Building Information Modeling Role in Industrialization of Buildings

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Abstract

The traditional methods of construction are not optimized from various aspects. This lack of efficiency throughout the lifetime of a project is evident during the planning, design, implementation and operation phases. To achieve ideal conditions in the construction industry to meet the annual housing demand on the one hand and manage the optimal conditions on the other hand, revisions need to be made in production of construction materials and products, design and implementation methods, construction technologies and incorporation of machinery. Meanwhile, industrialization of buildings could make great contributions to the housing demand where prefabrication and modular construction in factories and then assembling them within the workshop could increase the quality of project implementation and reduce the project time. The Building Information Modeling (BIM), which collects and documents all the required building information from the initial phase of planning till the operation phase during the entire lifecycle of the project in a data base, could be hired as an effective and efficient tool within the construction industry. Therefore, incorporation of BIM in industrialization of buildings could be used as a basis for investigation and assessment of construction projects. Also, it could improve the strengths and weaknesses of the industrialization process and addresses the design (integration) and construction (improved efficient management capability) phases. In this study, the role of Building Information Modeling (BIM) in industrialization of buildings and their interactions have been investigated.

Keywords: Building Information Modeling (BIM); Construction management; Industrialization of buildings

1. Introduction

Nowadays, traditional methods of housing construction do not meet the expectation of the society and considering the increased construction period, loss of materials and low quality performance, increased construction fees are observed. This construction process will lead to many challenges including [1]:

1. Inability to identify problematic issues due to having 2D layouts.
2. Delayed construction process due to problematic areas.
3. Lack of confidence in offsite construction due to presence of connections that necessitate onsite construction.
4. Duplication of efforts due to design flaws.
5. Increased required site monitoring to prevent conflicts between contractors.
6. Increased administrative burdens to obtain more information and change orders due to problematic areas.
7. First time installations from the contractors viewpoint.
8. Reduced efficiency for all parties involved during the project.

Consequently, the main characteristics of the construction industry at the moment involve inability in completion of the project according to the time layout and reduced profitability of this industry according to chronology [2]. Such features and characteristics stem from the difficulties and problems of the construction industry which are as follows [2]:

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1. No interaction between the design and construction teams
2. Short term thinking in the construction industry
3. Incomplete design information during construction
4. Poor management during construction process.

Two general approaches have been suggested by architects, engineers and the construction industry to overcome such problems. One approach includes industrialization of buildings where modular components, offsite prefabrication of components, quality control tests and finally transportation and assembly of such components on site would reduce the implementation time and improve the quality. The other approach recommends Building Information Modeling (BIM) as a common tool for every member of architectural, engineering and the construction industry societies (AEC) [3] and it provides integrated information regarding the entire building and a set of complete design documents and data stored in a database [4]. BIM could also pave the way for better interaction between the design team, client and contractors involved within the project and it could integrate the entire project life cycle including planning, design, implementation and operation in terms of procurement, sales and construction management. The better and more effective approach that can be hired to solve this problem is implementation of Building Information Modeling within the industrialization process of buildings to enjoy both the modeling and industrialization benefits and provision of more optimal conditions for construction projects within the housing arena.

1.1. *Definition of Industrial Buildings*

Different definitions have been given to industrialization of buildings. However, a comprehensive definition of industrialization states that in industrial method, building components are produced in the factory and then tested for various aspects of quality control and shipped to the workshop. In this method, the volume of construction operations at the workshop is reduced while the production rate is increased. In fact, industrialization of buildings is a precise process that considers the elements of time management, cost and quality standards for mass production [5]. Although industrialization, according to this definition, has countless benefits in mass production, it has great benefits for small scale construction projects. It is good to mention that mass production should not be interpreted as high-rise construction but should be investigated and evaluated separately in high-rise, mid-rise and low-rise construction [6].

1.2. *Building Information Modeling Definition*

Since the emergence of Building Information Modeling (BIM) as a new phenomenon in the construction industry, there has been no consensus on its definition and everyone has their own definition based on their viewpoint [7]: For some, BIM is a software application; for others, it is a process of design and documentation of building information which requires implementation of new policies, contracts, and relationships amongst project stakeholders.

Other definitions of BIM include: object-oriented modeling, project modeling, virtual design and construction, virtual prototyping, integrated project database [8]. In another definition, BIM is defined as a digital representation of physical and functional characteristics of a facility. Also, it is referred to as a shared reference of knowledge for formation of an information center and a reliable basis for decision-making during life cycle of a building from beginning to end [9].

In another definition, BIM has been defined as simulation of construction projects within virtual environments. By using the BIM technology, an accurate virtual model of a building, as a known building information model, is digitally made. Upon completion, the building information model including precise geometry and relevant data needed to support the design, procurement, construction and construction activities will be provided for implementation of construction [10].

2. Industrialization of Buildings and the Challenges ahead

Nowadays, incorporation of new technologies along with moving towards industrialization has revolutionized all aspects of human life. The construction industry has not violated this trend and has been subject to changes and developments. Yet, much of the implementation of residential buildings is performed traditionally. The roots of this problem need to be diagnosed. The question is why industrial implementation of buildings has not gained popularity amongst the public. Perhaps misunderstanding the concept of industrialization has led to this problem.

Industrialization of buildings is recognized as a fundamental and appropriate method to retrofit buildings against natural disasters like floods, earthquakes and wind. Also, incorporation of new construction materials particularly

conventional insulators common in industrialization process is known as a suitable solution to avoid energy losses [2].

Moreover, assessment of new construction technologies in terms of architecture and energy, debate over the advantages and limitations of construction technologies in industrialization of buildings [11], provision of required solutions to spread such mechanisms, studying the feasibility of localization, ensuring its compatibility with common construction patterns and finally spread of industrialization through provision of necessary training to ensure manufacturing quality and implementation of different systems is essential [12]. This could not be achieved without considering the challenges facing the deployment of new technologies [13]. Hence, application of dynamic management system approaches and industrialization technologies in construction projects from the perspective of project management role in optimal implementation of activities using new materials in manufacturing industry is necessary [14]. Incorporation of industrial systems of construction with an emphasis on the concept of sustainable development and provision of industrial construction systems is crucial in three scales namely high-rise, mid-rise and low-rise buildings. Accordingly, application of new technologies is believed to be in line with sustainable developments of the country in terms of economic, social, and ecological issues [6].

2.1. *Advantages of Building Industrialization*

Industrialization means modularity, observance of the project triangle, dynamism and flexibility, energy efficiency, continuity in the process, existence of a comprehensive system of collecting and spreading information, existence of training and finally paying attention to transportation production. Some of the main features of industrialization are listed as follows:

1. Avoiding the use of traditional and manual methods of construction
2. Serial and mass production of a prototype using repeating mass units (repeating)
3. Application of prefabricated members under controlled conditions and assembly of members in the workshop
4. Reduced energy and material waste during construction process [15].

2.2. *Importance of Building Industrialization*

At the moment, no technical or scientific barriers exist ahead of developers, industrial construction technologies are available for everyone and experts are completely familiar with this industry. Nevertheless, the only missing factor is shortage of supplies in industrial production. In industrialization process, construction time can be reduced and quality control will be more precise and eventually, a building with a higher service life will be obtained.

3. Significance and Characteristics of BIM

BIM is recognized as one of the most promising approaches in architecture, engineering and construction industries. Incorporation of BIM would yield more precise visual models of a structure and consequently, such models will support schemes that provide better analysis and control of manual processes. The moment that such generated computer models entail accurate geometric information that supports construction business, they are treated as completed models [10].

3.1. *Characteristics and Features of Building Information Modeling*

BIM technology is considered as one of the newest and most efficient means of information management that is currently hired by construction companies as a competitive tool to enhance project management capabilities. In this method, the components of the building are modeled and the characteristics of each dimension will be recorded. This data could be used as a common data base for the design, construction and project management teams [10].

1. N-dimensional modeling: these models include 3D modeling, time as the fourth dimension, cost as the fifth dimension and maintenance as the sixth dimension.
2. Design error detector using the "Clash Detection" capability.
3. Integration of design and project management.
4. Quick and precise access to management reports.
5. Integrated management of changes.
6. Simplified cost and time management.
7. Documentation and archiving the project information, and
8. Object-oriented modeling: in this process, each object is modeled once only.

4. The Role of BIM in Building Industrialization

BIM requires many functions to model the life cycle of buildings to provide a basis for new building potentials and provides new roles and interactions between the project team members. The moment BIM becomes compatible well enough, a more uniform design and construction process will be provided that could lead to increased quality and reduced time and costs of the final structure [16].

Industrialization is believed to be equal to modularization and it is expected that building components should be prefabricated in factories and be assembled in job site that necessitates the prefabrication of components in the factory so that no problem occurs during the construction phase. Meanwhile, maximum benefits could be obtained from BIM which are as follows:

1. Similar Design and As-built Construction

One of the biggest advantages of BIM is as-built construction. In this procedure, the design process is based on physical shape and real dimensions of the building. Hence, this plan is precisely applicable and results in the lowest dimensional tolerance.

2. Large-scale and Complex Projects

In large-scale projects, the volume of work and investment is so high that necessitates precise cost estimations prior to the start of the project. Incorporation of BIM has countless benefits including complex designs, detailed and optimized measurements and cost estimation, project management and coordination between the parties involved, speed in construction and reduced costs. In order to justify the increased costs of industrialization process compared to those of traditional ones, either large scale projects or mass production must be practiced.

3. The Relationship between Factors

Application of BIM would make the final design of the building understandable and therefore, the concept of design will ideally be exposed to other factors. First of all, the client is informed with the final design and then will optimize it according to their anticipations. The executer knows which methods to choose to conduct the construction procedure. The supervisor would also be able to the compliance of design and construction. The project manager would be able to choose the best methods of allocation of resources and timing for the project and eventually, the presale customer will have a clear picture of the purchased apartment. All such advantages stem from the fact that the final model is available and there would be no need for interpretation or visualization.

4. Optimized Project Management

BIM is recognized as a precious tool for project managers. The final model of the project could be used as an input for software like Autodesk Navisworks, Tekla BIMsight, Bentley Navigator and various stages of the project could be scheduled. Also, estimation of the labor force and materials would be easier. The construction stages will be available in detail. The location of cranes, depot materials, scaffolds and temporary facilities could be predicted. Time schedule is of great importance in industrialization process. Therefore, BIM could be a great means of allocation of materials, manpower and machinery to the ongoing projects.

5. Following the Project during Construction

Smartphones and tablets play an important role in communication and information transfer. Thus, BIM could be used as an effective tool to have access to your information [17]. One could carry also take the building model to the project site and share and discuss the required information with contractors and other parties involved.

6. Construction Phasing

Incorporation of BIM could picture all the possible forms of the project over time. There could be a possibility that your project was divided into phases. Some parts of the current structure need to be demolished and reconstructed. Yet, a development plan needs to be considered for the upcoming years. Also, building modeling could gather the entire construction phases in one place and could choose the best and most optimum plan for the project. Besides, it would give you a complete insight of the existing structure, the parts that need to be demolished and reconstructed along with the final design development of the project.

7. Faster Execution of the Project

Since an appropriate insight of the entire project steps is available, conflicts and problems are solved prior of the project and redesigning has been conducted as well, the executer knows how to execute the project. The client knows his expectations. Also, construction phase would be performed with minimal delay and problems. Consequently, investment and construction period will be minimized.

8. Component Interference Elimination

In industrialization process, most of the components, parts and panels are prefabricated in the factory and installed at job site. In case of interference between the components, the problem diagnosis possibility will be challenged. As a solution, during the modeling process, the building will be virtually designed and tested thoroughly. Hence, component interferences are solved and the structure will be redesigned again.

9. Reduced Duplication and Costs

During the modeling process, it would be possible to model a wall several times and demolish it; it would be complimentary and quick. Any duplication of efforts will be conducted virtually and there would be no need to take the hammer and destroy one's own property.

All direct or indirect BIM advantages are hired to reduce the final cost of the project. Hence, the structure is built with minimum material loss, demolition and delay.

10. Dynamic Design and Rapid Revisions without Error

Perhaps the biggest advantage of BIM in the design phase would be the dynamic nature of the modeling process because building models have the capability to adapt themselves with the changes made to the other portions of the structure. If revisions need to be made to the architecture or facilities of the model, this could be achieved via a few simple commands to synchronize the model with the changes. This issue is probable during the construction.

In two-dimensional CAD design, design revisions could be costly and time-consuming because the designs are not performed on a common platform. Thus, all the relevant parts need to be revised as well and the possibility of component interference increases. The later such revisions are made, the higher the costs will grow and delays will occur.

However, any revision in BIM, even in different sectors such as architectural design, construction, utilities and power, would result in changes in other relevant components. Moreover, the revisions are very quick and the possibility of component interference will be eliminated as the designs are performed on a common platform.

11. Cost Estimation of Materials

Since the final model is available, the cement volume, weight of rebars, number of tiles, switches, and the pipes could be calculated in minutes and consequently, the cost estimation process will no longer be a difficult and time-consuming task. Set the price for each item and estimate the final cost of the project. Try to have a complete list of vendors and Executers and do not be afraid of changes. Any possible change within the model would update the cost estimation automatically.

12. Precise Calculations

One of the advantages of BIM includes provision of precise and regular calculations of the different portions of the structure. The building model will be used as an input for structural engineering software and its response to different loading conditions (live, dead, earthquake, wind, snow, etc.) will be analyzed. Its weak points will be identified and strengthened. Incorporation of BIM facilitates the wall computation and overall energy analysis of the structure. This is achieved through separation of each room or space, the air required, channel size and its tube diameters. Also, the required light will be calculated. The electricity demand and its coincidence factor are also determined.

13. Data Exchange with other Software

One of the most important features of modeling with BIM, the possibility of importing the model into other software for any required operation. The model could be added to software like Tekla, SAP, Etabs, Robot, and etc. to perform the structural analysis and then, such analysis could be used to update the entire model of the building. This option could be used in all aspects of design and could enhance accuracy and speed. Also, the building model could be imported in visualization software and it could provide videos and photos of the actual project.

5. Conclusions and Recommendations

This article discusses the application of BIM in industrialization of buildings and its advantages to the construction business. In this regard, three factors namely time, cost and quality are recognized as the main and effective factors in construction projects. Therefore, incorporation of BIM in building industrialization has the following benefits:

1. As built construction will be practiced that could eliminate the component interference within the project and hence, it could reduce the duplication of efforts and costs.
2. Application of BIM would facilitate the communication between contractors, client, engineer, control system and subcontractors and the time that should be spent to resolve the conflicts between the abovementioned parties will be dedicated to the project.
3. Incorporation of software like Navisworks, Navigator, BIMsight in industrialization process would prepare a time schedule for different stages of the project. In case required, the development scheme for the upcoming years could be provided through phasing the construction process and therefore, provide optimal project management.
4. Building industrialization would reduce the construction period. Yet, since BIM provides a good insight of the project, the project could be conducted without any pause and with minimum construction problems.

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