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Investigating the Potential and Benefits of Using Building Information Modeling (BIM) in the Life Cycle of Construction Projects

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Research Article

Abstract

The construction industry is one of the broad, decentralized and highly indigenous industries of any country. In many countries, it is considered an indicator for growth and development or economic stagnation. This industry in Iran is currently experiencing a lot of inefficiencies, one of the main reasons for which is the lack of growth in the technical field. The use of traditional methods is known as one of the main factors inhibiting productivity in the construction industry in Iran, because most conventional techniques and their nature led to time delays and waste of resources. Therefore, it is necessary to use new technologies in this vital industry. Building Information Modeling (BIM) technology in construction projects is essential, including the benefits of using BIM, improving coordination and communication, increasing productivity, reducing errors, improving construction quality, etc. Therefore, in this research, the benefits of using this useful technology in the life cycle of a construction project have been investigated.

Keywords: BIM; Construction Project; Cost Management; Time Management

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1. Introduction

In the last few decades, the construction industry has faced several challenges, including low productivity and return on investment rates compared to other industries, gradual increases in labor costs, imposing unforeseen costs due to the lack of coordination among stakeholders, and time-consuming management. Changes in projects and a lack of timely and appropriate decisions have been faced.

During the last two decades, significant progress has been made in the field of knowledge and technologies for the management of civil and industrial projects with a focus on construction management. Among these advances is the use of Building Information Modeling (BIM) technology, which has many uses and benefits. Among its advantages: improving coordination and communication, increasing productivity, reducing design errors, managing execution and productivity after construction, improving construction quality, optimal management of resources including materials and equipment, and providing better decisions using powerful analytical and reporting tools. Therefore, the use of BIM in construction projects has a significant and influential role.

Building Information Modeling (BIM) have emerged as powerful tools for the Architecture, Engineering, and Construction (AEC) industries. When integrated, they allow for applications in some different areas, including design review (Roup´e et al.,2016), production planning (Muhammad et al., 2019), and construction safety (Hafsia et al., 2018). The argument often put forward when compared to non-immersive, desktop visualization, is that immersive VR provides a better understanding of scale and detail and allow people to enter and inspect environments in a similar way as they would do in real life (Han and Leite, 2021; Wolfartsberger, 2019). More recently, immersive VR has been extended to support multi-user sessions, where several participants can experience the same model at the same time (Du et al., 2018). For design review sessions and model inspection, this has been shown to enhance communication and improve collaboration among participants (Heinonen et al., 2022).

Also, despite all the advantages and benefits of this technology, it also faces some challenges. The benefits and positive effects of information models in the construction industry are such that they can easily transform many critical aspects of the project and contribute to the final success of the project. The successes achieved by information modeling are felt in all aspects, including the impact on time and cost, but the major advantage of BIM, is its integrity ability. In this research, an attempt is made to examine the benefits of this technology by reviewing published articles and interviewing experts.

2. Literature Review

Due to the prevalence of building information modeling in different countries, studies have been conducted in various fields and aspects of insurance, which are as follows:

Nor Diana Aziz et al. (Diana Aziz et al., 2016) in research titled "Building Information Modeling in Construction Management: Opportunities for Operating Managers" have discussed the impact of using building information modeling in construction management and its benefits by reviewing previous research. Among the critical effects of using BIM, it was determined as follows:

1- Effective operating cost 2- Decision making in less time 3- Suitable information sources for decision-making 4- Better documentation system 5- Establishing cooperation and work flexibility 6- Updated information and interference control.

In another study, Becerik-Gerber et al., 2012, on "application fields and information required for construction management based on building information modeling" by preparing a questionnaire and interviewing experts familiar with this technology. Investigating the practical fields of using building information modeling in construction management. In this research, two possible information scenarios during construction management have been discussed and answered in the framework of building information modeling.

Kim and Hong (Kim & Hong, 2018) in article entitled "A Study on Applied Services for Effective Crisis Management Using Building Information Modeling" examined the achievement of effective crisis management using building information modeling.

Peter Metejka et al. (Metejka et al., 2016) in research entitled "Incorporation of building information modeling in the final stages of the project life cycle in unprepared environments from the perspective of construction management," the benefits of using building information modeling in the operation phase of projects They explain that in the previous phases, no activity has been done in the field of building information modeling. In this study, three different projects that were used in the exploitation phase of BIM have been examined.

Wang et al. (Wang et al., 2015) in another study titled "Considering construction management in the project design phase using building information modeling: framework and case study", They presented a standard framework for using building information modeling in the design phase.

Alexander Nical and colleagues (Nical & Wodynski, 2016) in an article entitled "Improving construction management using BIM" concluded that to optimize construction management, building information management should be maintained from the beginning of the project to the operational stage. to be Also, the applications of building information modeling in the life cycle of the building have been investigated.

Al-Ashmori et al., (2020) and his colleagues distributed 590 questionnaires to the firms and experts in this field. They concluded statistical analysis that efficiency, time, cost, cooperation and communication among individuals have been the most significant advantages. Moreover, trust, respect, commitment and the initial interaction can be regarded as Stimulants.

Mohammad Farhan Arshad et al. (2019) Suggested a standard framework for the projects using the BIM in article entitled "Arbitary Risk of the BIM".

Yije Kim et al. (2022) determined the necessary information for the data collection of the BIM-based on the drawing requirements of construction at the documentation stage by using Delphi Method.

Sonmez et al. (2022) offered the intelligent payment management system for the advancement of the construction project, which was modelled by the BIM. The mentioned intelligent system makes it possible to make payments to fewest pitfalls compared to conventional methods.

Cheng Lin et al. (2022) studied the problems regarding the repairs and maintenance of the BIM and discussed the effectiveness of the recommended system by conducting a case study.

Rojas et al. (2019) in the research, investigated the usage of the BIM and the application level of BIM. Finally, they provided the evaluation tools of BIM at the stages of designing and planning the construction projects.

Wei Zheng et al. (2022) Conducted research regarding the usage of BIM in the implementation of prefabricated houses, industrialized buildings, reconstruction of prefabricated houses in the virtual ambiance, and the pre-implementation stage.

Hongwei Li and Chongyu Wang (2022) recommended the use of BIM technology in green buildings and their constant evaluation.

Yinchen You et al. (2022) examined the safety of high-rise metal skeletons of buildings by analyzing the limited factors and BIM technology.

Lirong Liu et al. (2022) analyzed the management expense of civil projects by applying the BIM technology.

AL Rahhal et al. (2022) offered a framework for choosing suitable substances to prepare the floor of buildings by utilizing the AHP technique, value engineering, and BIM technology.

Wangchao Shen (2022) Manage the consumption of construction materials by utilizing the BIM technology and internet of things.

Gen Li and Haining Tian (2022), in a review paper, analysed the articles published from 2012 until 2022. These articles focused on the management of energy consumption in the buildings and the upcoming trend of the BIM.

Baydaa Hashim Mohammad et al. (2022) in a review paper, examined the relations between the BIM and the Internet of Things.

Knight et al. (2010) believed that the compensations of interference of mechanical and electrical installation with the elements of building sometimes account for up to 25% of the total cost of project, which can be avoided in the design stage by BIM technology.

Parvan et al. (2012) from study of 30 construction projects that have utilized the BIM technology, concluded 30% of the time needed for designing, 10% of the time required for constructing, 16% of interference and repetitions in the entire project will be reduce.

Chelson (2010) concluded that the use of BIM and increased collaboration between team members significantly reduced interference by 90% and also reduced delays in the construction process, ultimately resulting in 35%time savings, 20% in expenses. BIM improves project control and planning system.

Kymmel (2014) found out that recognizing the interference between structure and mechanical, electrical installations would be perfectly feasible before the stage of implementation by using the BIM.

Eadie et al. (2014) researched about barriers of BIM in the United Kingdom. These barriers are as follows: the cost of purchasing software and hardware, the cost of instructing the staff. The lack of technological knowledge, legal problems, Lack of prospects, Lack of culture of Flexibility, not approval by senior manager of the Project, not acceptance by the staff, and finally, the change of methods.

Kekana et al. (2014) reviewed the articles written, and the research conducted in South Africa. They detected the barriers of BIM. They concluded that the main problems are as follows: the lack of standard regulation regarding the use of BIM, the lack of designers familiar with this technology, the lack of insurance policy to support the technology.

Zahrizan et al. (2014) studied the construction industry in Malaysia by handing out questionnaires to the experts. They reiterated that the lack of awareness regarding BIM, the high price of BIM, the timing of BIM, the unwillingness of employers, customers and contractors have been the significant barriers. They also added that the obligations imposed by the government and promotion BIM on the part of all the teams involved in the construction industry would guarantee the success of this technology.

Santos et al. (2017) reviewed the research conducted in the field of BIM from 2005 until 2015 and separated all the research into nine main categories, which are as Follows based on the order of frequency of articles:

1- collective environments and interoperability 2- sustainable construction 3- acceptance and standardization of the BIM 4- programming the BIM 5-image processing and Laser Scanning 6- the

management of facilities and the analysis of safety 7-the management of construct 8-review papers 9- BIM and particular information

Jin et al. (2017) utilized the BIM to model construction information and referred to lending support to the BIM in many countries, including China.

Cao et al. (2017) researched the effects of obligations imposed by the government and related agencies to support the use of BIM technology.

Hanna et al. (2014) conducted a Survey of experts and reviewed the activities done, mentioning the advantages of the BIM for electrical installations.

Smith (2014), who did an article entitled the utilization of the BIM and global strategies studied the published papers, mentioning the innovative and achievements of countries in this field.

Jones and Bernstein (2014) researched the ten largest construction markets of the globe, including China and India, which showed that the usage of the BIM is on the increase. The utilization of BIM will reduce 56% of changes and 59% of disparities in the construction process.

Giel and Issa (2013) measured the payback period which using the BIM.

Khosroushahi and Arayici (2012) surveyed of contractors in Finland, reviewing the published articles and studying the advantages and challenges of using BIM.

Morlhon et al. (2014) researched the advantages of the BIM and reviewed the articles published in this field.

Yu Cheng Lin et al. (2016) Conducted research on the management of the BIM to boost the efficiency of the BIM implementation with the help of contractor.

3. Research Method

This research is descriptive-analytical. In the first stage, by studying library resources and related articles and the work processes related to the management of construction projects using previous researches and conducting interviews with experts, managers various applications of BIM were extracted. In the second stage with the analysis, the results were categorized according to the life stages of the project.

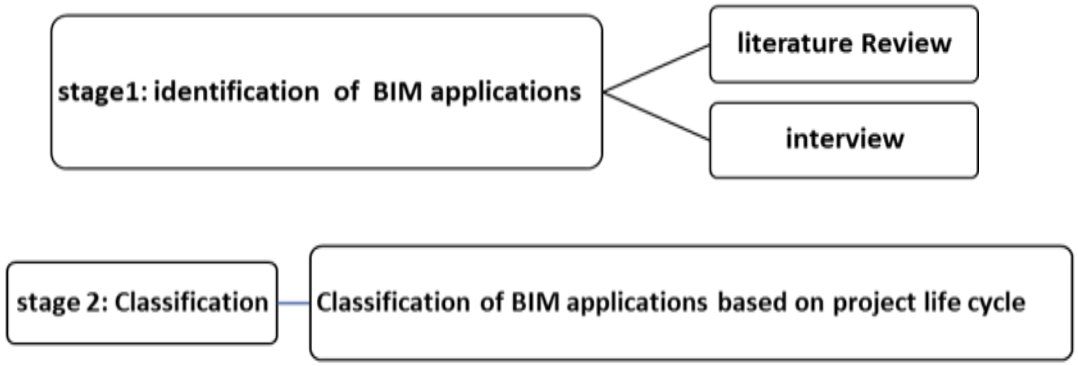

Fig 1 Research steps

4. Introduction on BIM and its Applications

Using of construction information modeling and new software and hardware technologies has opened new horizons for the construction industry in developed countries. When we use BIM technology, all the designers and stakeholders of the project work together as a team in a

coordinated and integrated manner. All ideas are evaluated without much cost and time. In this system, unlike the traditional method, all dimensions of the project, are simulated with rich information and planned for each one of them before construction. Therefore, from the begin, specialists from different part will have a single mental image of the project (Fazeli et al., 2020).

The use of the construction information modeling system causes the instant exchange of information between the project's stakeholders and as a result, minimizes design errors and interferences, the project will be completed on time. Also, increase productivity and annual financial turnover. By adopting advanced digital techniques for construction projects, the quality of design and construction is improved and the economic problem of construction industries is reduced (Srao et al., 2020). On the other hand, BIM is a great help for integrating the people involved in the project. Therefore, with this method, the problem of people's lack of knowledge about other specialties and disciplines involved in the project has been solved. Great goals can be considered for projects that use this technology (A.B, 2020).

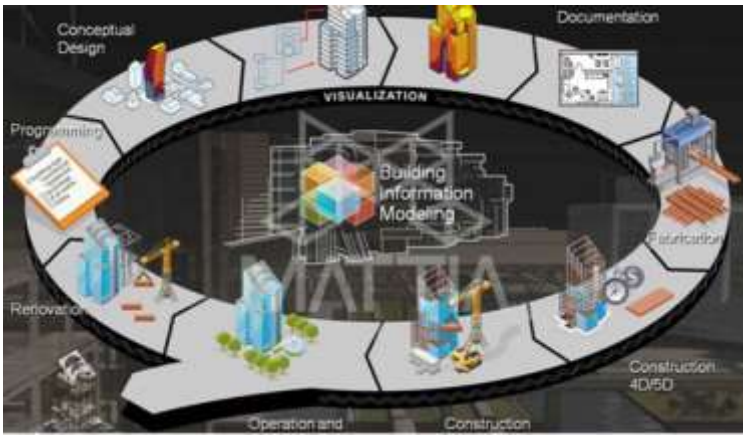

Fig 2 BIM technology applications in the building life cycle

Fig 3 BIM level and dimensions (Panteli et al. 2020)

4.1. BIM Application in the Pre-Construction Stage

a. Carrying out integrated design of the project and identification of interference

The BIM process makes it possible for the design team to simultaneously work on different parts of the project and share the 3D model of the project. At any moment, all team members are aware of the latest changes in the final model. This creates more empathy between the members of the

design team and reduces errors in design, reduces rework and increases the productivity of staffing, reduces the duration of project design and presents and reviews various design scenarios in three dimensions.

In the BIM process, it is possible to adapt the models designed by different members of the design team in a three-dimensional environment and to identify possible collisions between different parts. This is despite the fact that in the traditional process of design, identification of interactions and collisions between other parts is done by human power, which is time-consuming. While interference is identified by software in the BIM, which has higher accuracy.

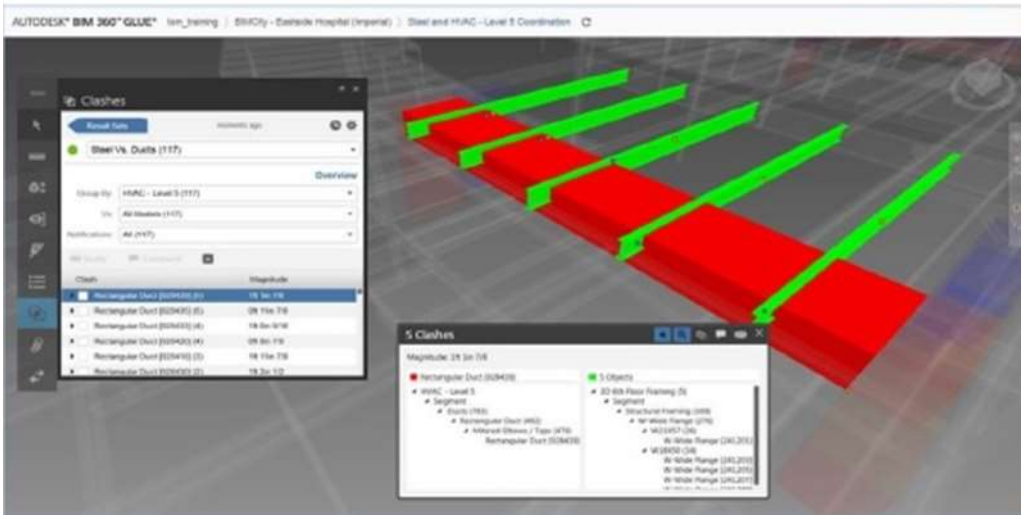

Fig 4 Detection of facilities channel interference with composite roof beams

b. Quantity surveying and estimating of the project using 3D model

Measuring in the traditional way depends on the experience and expertise of human resources. In the traditional method, meterer is not aware of the latest changes applied in the project, as a result, the project estimation is always accompanied by errors. In the BIM process, by using the one-dimensional model of the project, the exact amount of materials, manpower and machinery required can be met, and by using the price list, the actual cost of the project can be determined, thus increasing the speed and accuracy in meters and the project is estimated.

The use of BIM for measurement and estimation increases the speed and accuracy of the measurement, allows for a more accurate examination of the cost of different design scenarios, reduces disputes and claims, and estimates the cost of the project according to the latest changes in the design.

c. Creation of 4D and 5D models for project management and control

The BIM process connects the project schedule to the 3D model. As a result, the project management team can objectively observe the physical progress of the project. Four-dimensional models allow for a more accurate understanding of the sequence of different construction stages, definition of "what if..." scenarios to choose the best method, workshop management by showing the progress of work, determining the location of machines, analyzing the movement of machines and cranes. They provide control of accesses, identification of interactions between work team and planning of resource allocation and estimation of values.

4D models (3D model plus time dimension) can be connected to the cost of each activity. by five-dimensional model, total and partial cost and the S-curve of the project can be created, managed and controlled.

The BIM process allows accurate estimation of the materials used in the project by using a 4D model. In this way, the time distribution of the amount of consumed materials can be easily calculated. As a result, the supply chain management and project procurement can be adequately planned and controlled. Another advantage of the BIM process is the automatic preparation of the list of required materials and equipment on a weekly or monthly basis based on the time distribution of the materials and equipment used. One of the advantages of this approach is timely ordering and supply of materials, optimal use of workshop space, and significant reduction in resource and time wastage.

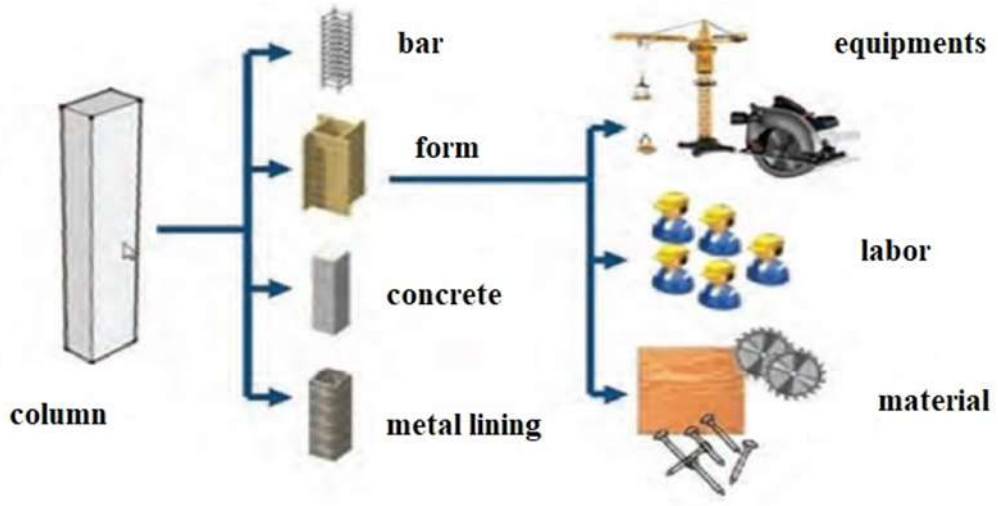

Fig 5 Estimation of the volume of materials and manpower and machinery in the meter process by BIM

4.2. Use of BIM in the Construction Phase

By creating a 3D model of the project using the BIM process, the project management team will be informed of the changes made in the project at the end of each working day.

Optimizing the location of temporary facilities, material depots, machinery locations, etc., is of great importance in industrial workshops such as refinery construction workshops that are limited in terms of working space. Optimizing the placement of temporary facilities and machines reduces transportation distances, increases the productivity of machines and manpower, and reduces the time and cost of the project.

The BIM process provides the possibility of preparing accurate as built maps by using laser scanning technology and photogrammetry technology for renovation, treatment and maintenance management.

This technology leads to the production of "electronic 3D model" containing complete dimensional information of the industrial area, including structural, mechanical, equipment and piping parts. BIM technology, generate executive plans for installing new equipment and systems, and product Dismantling plans for parts of the existing situation that must be dismantled.

Printed maps during the period of operation and maintenance of the project lead to the creation of a large volume of documents and maps, which increase in volume during the life cycle of the project, and their maintenance is costly.

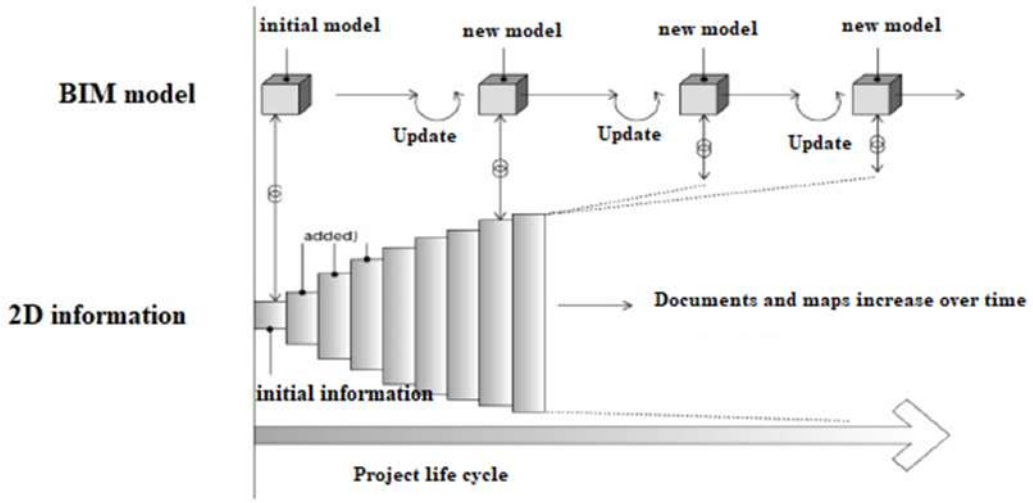

Fig 6 Comparison of the use of BIM and 2D maps during the project life cycle

This despite even though in the case of using 3D models, a 3D model is permanently updated every time the project is renovated or repaired. Another problem in two-dimensional maps is their lack of integrity. So, in case of a change in one part of the project, all the maps must be modified separately. This is despite the fact that in 3D models, the desired changes are applied only once in the model. Management and maintenance system by using of BIM process from connecting the 3D model to the information database related to the period of operation, repairs and maintenance, including: technical specifications of equipment and facilities of mechanical and electrical structures, specifications of manufacturers, sellers and supporters of each of equipment, operation, and maintenance period of each equipment, prioritization of each equipment based on strategic structure, necessary instructions for repair and maintenance of each equipment, price of each equipment and costs related to supply, replacement, and Project maintenance is created. Among the other applications of BIM is the analysis of the energy consumption in the building. Analyzing energy consumption using traditional methods is very difficult and time-consuming. The BIM team uses parametric optimization solutions at different stages of building design, which determines the target variables and functions according to the client's request, checks hundreds of models by algorithm and selects the best option according to the function. specifies the target. Optimization can be used in different stages of design and for different purposes, some of which are as follows:

Optimizing the building form in different stages: by defining the objective function and variables considered by the employer, the objective function is determined based on climate analysis, project topography, architectural concept, structure details, construction costs, and other parameters related to the project.

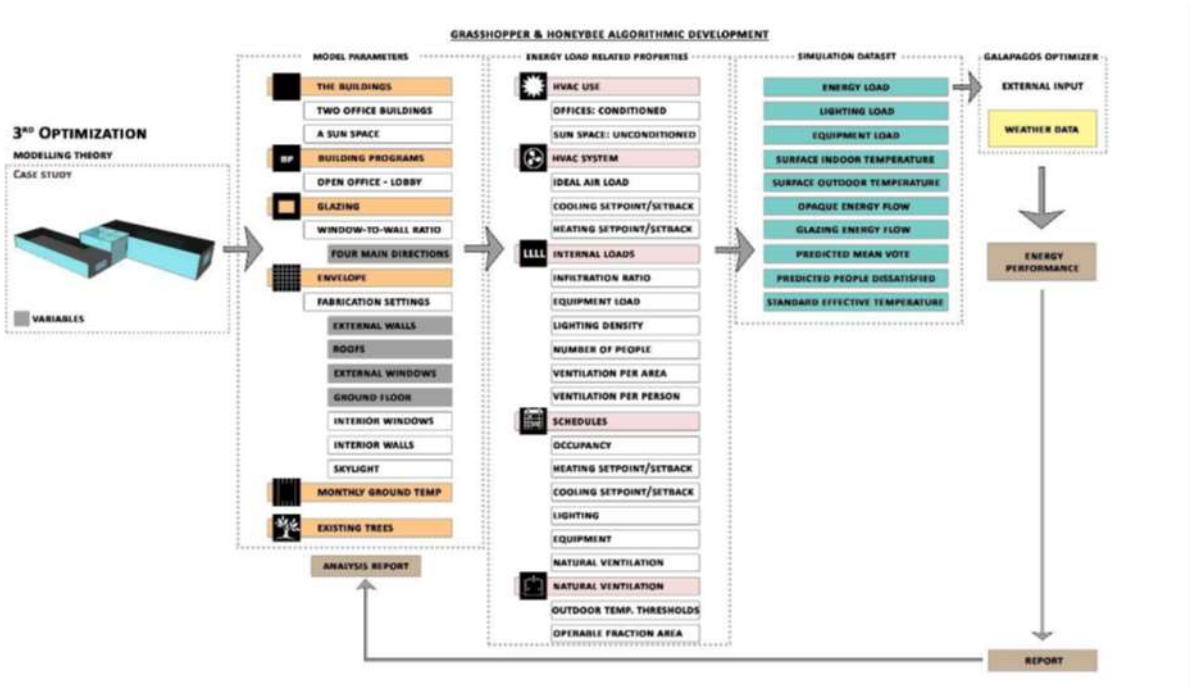

Fig 7 Steps to optimize energy consumption in the building using BIM

Optimization of canopies: This optimization of the design stages of the details of the shell, whether the design of the system of canopies or the comparison of different modules of the canopy system as a second shell, is done by considering the factors of visual comfort and other parameters related to the project and the client's needs. Optimizing the design module of all building components, including walls and facades, which is used to reduce the amount of material wastage, and gives the employer a suitable tool for choosing structural and architectural modules, including the facade and building shell. BIM applications during the life cycle of the construction project are summarized in Table 1.

Table 1 BIM applications in different stages of the life cycle of the construction project

Row	Construction stage	Application
1	Pre-construction	Integrated design of the project by different groups and the possibility of identifying collisions and interactions between plans
2		Quantity surveying and estimating of the project by use of a 3D model
3		Providing virtual reality and augmented reality models to create a correct and complete view of the project and control implementation using extended reality models
4		Creating four and five dimensional models in order to comply with the full scope of the project and not

		to forget some of the project activities and costs and to create a better view of the construction.
5	during construction	Intelligent supply chain management, procurement and stockpiling of the project
6		Interference detection between different project components
7		Creation of four and five-dimensional models for project management and control
8		Optimizing the movement of heavy machinery and cranes
9		Optimizing the location of the workshop
10		Data entry of all project equipment and documents to different elements
11	After construction	Creating an intelligent program to manage the maintenance and operation of the project
12		Preparation of detailed plans such as construction (As Built) using laser scanning and photogrammetry technology and intelligent monitoring of project progress

5. Conclusion and Discussion

The main applications of Building Information Modeling (BIM) in the life cycle of construction projects are: 1- Design and Modeling: BIM allows engineers and designers to create accurate 3D models of buildings and infrastructure and rapid evaluate design improvements, changes and proposals. 2- Project planning and management: Using BIM, digital project models can be used as a reference map for planning, resource management and coordination between different project teams. 3-Analysis and simulation: BIM allows to perform various analyses such as static and dynamic analysis, cost and time analysis, and simulations of construction and post-construction operations. 4- Execution and construction: using BIM, detailed information related to the construction and execution of the project is obtained and translated directly from the digital models, and therefore can help improve the quality of construction and reduce errors. 5-Productivity and benefit: After construction is completed, BIM can help operational and maintenance managers manage detailed information about infrastructure and equipment and improve productivity. 6-Management of changes and maintenance: BIM allows managers of changes and maintenance to manage detailed information related to the history of the current state of the building and support correct decision-making. By replacing traditional processes with digital processes, this helpful technology improves the efficiency and quality of construction projects and helps better coordination between project team members. According to the authoritative report of McGraw-Hill, in recent years, the benefits of using BIM are: Improving 75% coordination and communication of work teams, 48% reduction in rework and change orders, 57% reduction in errors during the design period, 52% reduction of errors and omissions in project documentation, 48% increase in the description of new services, 53% increase in new business markets Also, the long-term benefits of implementing project information modeling are as follows: 17% reduction in project duration, 16% increase in project profit, 12% reduction in project costs, 28% reduction in lawsuits

Some of the barriers influencing the use of the BIM are the lack of support from the authorities, the lack of obligation regarding the use of the BIM, the lack of instruction facilitating the use of the BIM in related organizations, the lack of official rules to support the implementation of the BIM. To remove the barriers mentioned above, there should be cooperation among those who decide at different stages. The use of the BIM will be widespread when governments, communities and guilds embark on introducing this innovative method and raising awareness regarding it. In the next stage, they initiate making laws, providing the related applied standards and the standard BIM Contracts. Following the completion of the acceptance stage, the stage of inter organizations embark on the removal of difficulties and challenges faced with interested parties while interacting with each other.

The results of this research will have widespread applications for the senior managers and contracts involved in the Construction industry. The potential clients will be able to improve the BIM by being inspired by prioritizing the barriers and challenges and providing implementation at the organization stage and interorganizational stages from the technological and educational perspectives.

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