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Examining the Practicability of Building Information Modeling In Improving the 4th And 5th Dimensions of Construction Projects: A Review

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Abstract:*In the realm of information technology, Building Information Modeling (BIM) has begun to take a foothold in the construction industry due to the myriad upsides lie in its implementation. Whilst there has been a significant studies concerning the investigation of how BIM could benefit the 4th and 5th dimensions of construction projects, there has been a dearth of literature and research delving into its practicability in reducing the cradle to the grave projects' duration and expenses. In light of this, this paper aims at reviewing the past studies undertaken in the mentioned areas so as to determine the extent to which BIM adoption have accrued benefits to project managers and cost estimators. It is found that BIM implementation would have a tremendous positive impact on simplifying diverse phases of construction projects, which can set the stage for a considerable reduction in the completion time and cost of projects.*

Keywords:*Information Technology, Building Information Modeling, the 4th and 5th dimensions of construction projects*

I. Introduction

The management of construction projects has become immensely complicated [1-3]. The mutual interdependencies among various stakeholders like authorities, financing bodies, architects, contractors, lawyers, engineers, suppliers, and trades is one of the factors that has led to this complexity [4]. The information and communication technology [ICT] has recently transformed into a fast-pace development resulting from the increasing complexity and errors occurring during projects [5]. The Building Information Modeling [BIM] proliferation occurring in industrial and academic contexts during the 1990s as a new Computer Aided Design (CAD) paradigm was the most important shift in ICT for construction industry [6]. Presently, BIM – defined as "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's lifecycle" [6].BIM would be regarded as a panacea to reduce the deficiencies occurring throughout the whole lifecycle of construction projects owing to the innumerable advantages involved in its adoption.These benefitscomprise minimizing design error, reducing rework, increasing work efficiency and cooperation amongst team members, facilitating the process of delivery and procurement, and reusing the wastages of materials [7-12].

Time and cost control in a construction project has been one of the most important issues in construction since the advent of the construction industry. Various factors are involved in the uncertainty of project development. Several integration methods and models in multiple studies have been developed emanating from a lot of efforts made in order to integrate schedule and cost in construction projects. However, it is very common that projects are seldom completed on time [13]. Currently, a number of tools regarding time control have been developed, some of which differ for their functions, and some are only designed for certain projects [14]. Although the AEC industry have put a lot of efforts to develop techniques considering only quantitative factors concerning project cost control, the qualitative factors such as "client priority on construction time, contractor's planning capability, procurement methods and market conditions including level of construction activity have been ignored" [15].

Cost engineers, quantity surveyors, construction economists and project managers are the main professional disciplines providing specialist project cost management services around the world. Quantity Surveying is a profession with origins in the United Kingdom and is a professional title recognized mainly in Commonwealth countries. Cost Engineering is the term mainly used in North and South America, China and some parts of Europe. Construction Economist is used in some European countries and in other parts of the world as an alternate descriptor for the service. These three professional titles are not recognized with cost management services largely carried out by Project Managers as part of their suite of services in other regions, particularly in Europe. Since few countries require official registration to practice as a professional in the field, cost management is not the exclusive preserve of these professionals, so that a range of other professionals and technicians also carry out these services [16].

II. Findings

2.1 Traditional and BIM Estimating Process

Differences between the traditional methods and BIM methods exist in both the quantity take-off and estimating steps. Traditionally,the responsibility of an estimator lies in the quantity take-off for a commercial construction project in the United States. A thorough review of the contract documents including the general conditions, working drawings, and specifications is regarded as the first step of time-consuming process of quantity take-off. The format of output from a traditional quantity take-off is typically in the form of a spreadsheet, or bill of quantity, thateither lists work assemblies and systems or the output may list may be more detailed lists of materials organized by the Construction Specifications [17]. In general, the simplified example of steps involved in the traditional quantity take-off process incudes [18]: First the project is divided by the estimators into parts, such as building, phase, or level. Next, assemblies within each part of the project are identified by the estimator. Once the assemblies have been identified, then the estimator calculates all the material items within the assembly. The output from a quantity takeoff is generally a list of materials with quantities assigned to each line item. In contrast, due to the fact that BIM automatically generates a quantified list of materials, a BIM generated QTO differs from the traditional method in the amount of effort and time required from the cost estimator, as suchthe labor intensive task of QTO is no longer the responsibility of the estimator resulting from the automatic QTO [17]. Although a BIM generated QTO has a line item for every object in the model, details about the materials contained in the BIM generated list may vary widely depending on the level of project definition and subsequent information about the materials for objects in the model. Eliminating the quantity take-off activity from the cost estimator's project responsibilities could be contemplated as the ultimate benefit of using BIM. As a consequence, more time can be devoted to completing value added tasks such as risk analysis and project simulations by the estimator [17].

2.1.1 Steps to validate a BIM-generated quantity take-off

The followings are steps in the BIM-QTO validation process based on the cost estimators interviewed [19]:

1. Checking the design model manually against the traditional 2D set of drawings for the project.
2. Comparing quantities from BIM with quantities from a traditional set of drawings.
3. Comparing the design model with historical information from similar projects.
4. Ensuring dataset is output in a usable format.
5. Reviewing the QTO dataset for 'global' holes using Uniformat as a guide.
6. Focusing on each level in Uniformat relevant to the project Level of Development.
7. Verifying the integrity of the data from the design model based on the element's properties.
8. Confirming accurate use of model elements, such as correct slab element based on its location (e.g. slab on grade or elevated slab).
9. Mapping elements from the model to a complete data assembly (e.g. formwork).
10. Selecting key items in the model for query about additions and/or deductions (e.g. deduct volume of concrete for embedded pipe in slab).
11. Verifying that complete dimensional data is exported.
12. Checking dataset manually against model content.

2.1.2Guide for information-interoperability between practitioners

The information exchange requirements between project stakeholders through the framework as a guide are defined at this point. Three factors are needed to be in place to allow for interoperability in the computerized information exchange between project stakeholders in accordance withNBIMS [20]. These three factors are:

1. The format for information exchange
2. Specification of the information to be exchanged and when to exchange the information
3. Standardized understanding between stakeholders of the information to be exchanged.

In addition to the three factors necessary for interoperability, the information needed to support an exchange can be divided into seven groups [20] as below:

1. WHO? This category defines the one demanding for the information.
2. WHY? This category gives a proper answer to the question why the activity occurs and is connected to the stakeholders (who?).
3. WHEN? In this category,the design development phase identifies the project phase.
4. WHAT? The entities, objects, and properties of objects are defined along with the expectation delivered between stakeholders.
5. To WHOM? In this category, the stakeholdersare asked to complete the task identified.

6. HOW? The development of the design and construction of a project based on the resources are defined in this category.
7. INPUTS & OUTCOMES? The data utilized during the process of the creation of a facility is referred in this category. Additionally, the data created by a model such as the quantity take-off is included.

2.2 The introduction of an innovative philosophic stance for cost-estimation using IFC

Shenet .al [21] carried out a research in order to introduce a new philosophic stance for cost estimation to address the development of model based cost estimation. Additionally, the importance of contextual information, and the needs of extension of pricing information according to the general process of cost estimation by using the IFC standard are addressed.Fig 1 demonstrates the general process of cost estimation in a general framework of input, process and output so as to facilitate the automationof the cost estimation by using the IFC design result.

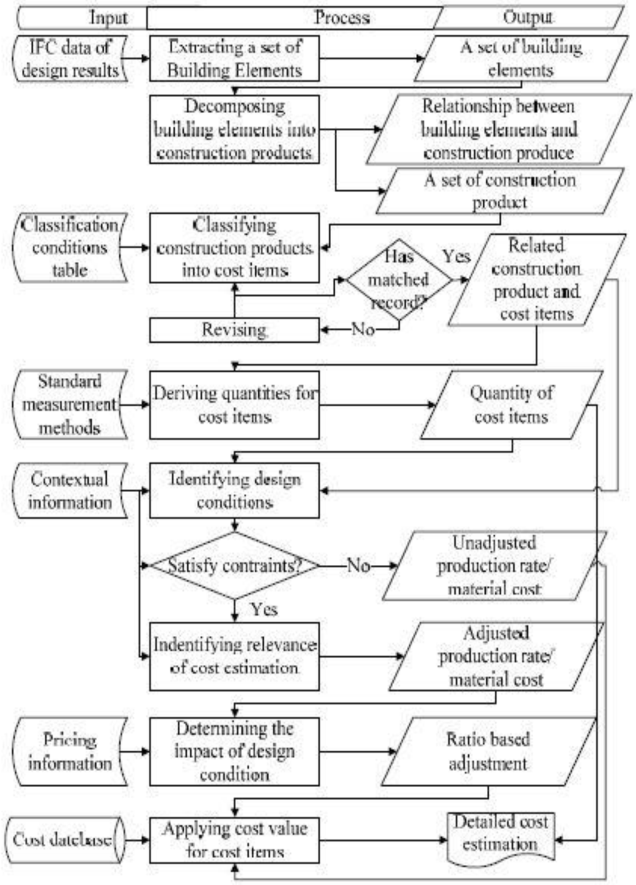


Figure 1: General cost estimation process by using IFC (adapted from [21])

The authors delineated how the contextual information can be used in IFC model. Once the quantity surveyor has received objective information about a product model, then they may translate it into subjective values. Locating objective information, recognizing it in the immediate situation or in the past, evaluating the objective information, combining the information together, and then implementing it as a certain value of estimation are the mentioned translation required. The importance of identifying context and relevance and their impacts on construction costs in order to automating the creation of cost estimates are emphasized through this example.

The information requirement for the cost estimation can be summarized into 5 aspects which could be described through the IFC standard: the building products information, the cost item information, the quantity information, the resource information and the price information.An automation of cost estimation based on decision making of pricing information rather than only its prediction can be created by modeling the input information of cost estimation [22].

2.3 The impact of BIM as to MacLeany's curve

Time–effort distribution curves can graphically indicate the different cost and saving patterns caused by BIM adoption, and also can inform stakeholders as regards improved BIM implementation. Lu et.al

[23]administered a research with the aim of demystifying the time–effort distribution curves of a construction project with BIM support by comparing them with the curves of a construction project without BIM support. Case studies of two housing projects, one with BIM implementation and the other without a BIM element were introduced.

As can be seen in Figs2 and 3,the time–effort distribution curves of the non-BIM and the BIM project using the normalized time–effort data were produced. The normalized effort data points are linked and plottedby the process involved in the two-dimensional coordinate system. The effort spent on each unit of the floor area (unit: HKD=m2) and the progress of the project ranging from 0% to 100% are denoted by the vertical axis and the horizontal axis respectively.

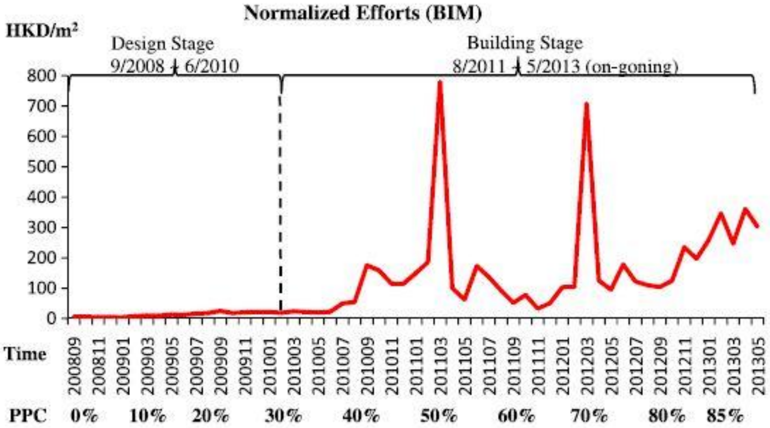


Figure 2. Plotted time–effort distribution curve of the BIM project (adapted from [23])

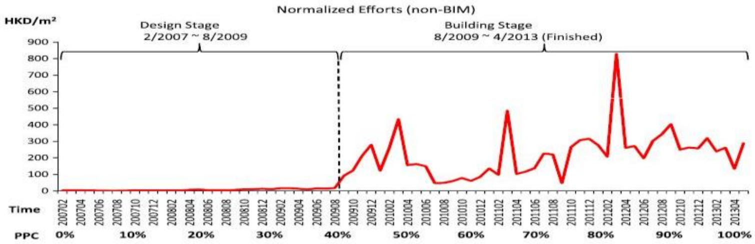


Figure 3. Plotted time–effort distribution curve of the non-BIM project (adapted from [23])

The authors arrived at the conclusion that the cost or, in other words, priced effort, incurred at the design stage of the BIM project is to be larger than that of the non-BIM project. In order to make this more conspicuous, the S-curves of the two projects at the design stage were produced (see Fig.4).The aggregated normalized effort of the BIM project is larger than that of the non-BIM project at the design and early building stage as illustrated in the S-curves in Fig.5. However, the aggregated normalized effort of the BIM project is outweighed by the non-BIM project.

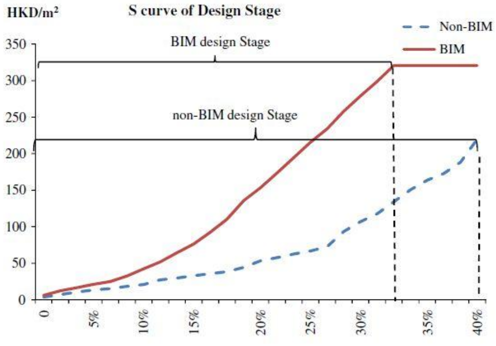


Figure4. S-curves of the BIM and non-BIM projects at the design stage (adapted from [23])

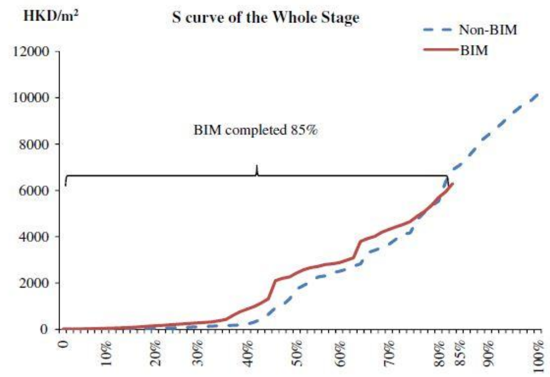


Figure 5. S-curves of the BIM and non-BIM projects throughout theAEC stages (adapted from [23])

Despite the fact that BIM implementation did incur extra expenses at the design stage, the expenses could be offset at the building stage. Furthermore, BIM implementation could shorten the design stage by providing a platform for examination of design options rather than prolonging the design stage, early involvement of all team members, and open information sharing.

2.4 Challenges of implementing BIM by cost estimators

A brief list of user-related resistance and limitations to the use of BIM by cost estimators is mentioned as below:

- Down market – limited investment from large companies [24]
- Spending enough time by too busy people on using new tools or changing process [24]
- Lack of training/understanding to use new tools [24]
- Modeling to correct level of detail and for intended purpose[24]
- Quality of the BIM Model [25]
- Automated Quantities [25]
- Lack of Standards/Software Incompatibility[25]
- Sharing Cost Data Information [25]
- Business Changes[25]
- Legal/Contractual/Insurance Issues[25]
- Learning curve [26]
- Access / update coordination[26]

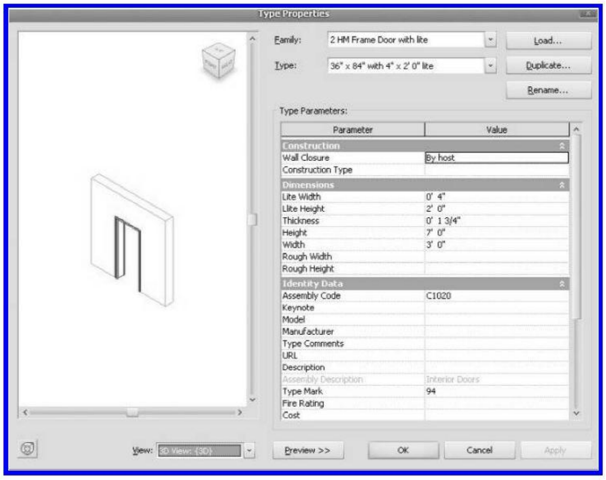
2.5 The utilization of BIM software in improving the easiness and accuracy of calculation of projects' duration and cost: Case Studies

In this section, the practicability of BIM software in simplifying the process of both time and cost calculation based on the Case Studies is investigated.

2.5.1 Benefits of the adoption of Revit in reducing time and cost of a project

Zhang, D., &Gao, Z. [26]conducted a study in order to depict how the use of BIM techniques can lead to a significant reduction in project costs and improvement in project schedule benefiting all the stakeholders of a construction project. In doing so, Autodesk Revit Architecture was used in the study as BIM software for developing project control, and by generating data from the case study project with a local Architect and Construction firm in Fargo, ND for discussion and analysis. The case study project is Scheels All Sports Retail Center, Springfield, IL, owned by Scheels Sporting Good Chain. It was found that the 3D models created in Revit during the case study were not only simple graphics of the future building; all the data about a project all through the project lifecycle could be recorded. Revit model is capable of defining each element entered into in a great detail. To illustrate it more explicitly, when a door has been created in Revit Architecture, then its basic properties like material, type, thickness, height, width, fire rating, etc., are defined as well.

The detailed properties of the door created as well as its 3D view is shown in Fig.6. The viewer is given direct and highly detailed information through this function. Moreover, the information is changeable according to the project plan anytime. The information in the database is not isolated by itself in the meantime, but linked with each other. Therefore, once one has been changed, then the others related are automatically updated. Likewise, the plans, drawings, specifications, takeoffs, etc. are all saved electronically in the same database as they are created. They all can be generated through relevant views. To make it clear, the column materials quantity take-offs is illustrated in Fig.7; it was automatically recorded in the database during the time ofdesigning, which saves a huge amount of time compared to the traditional process. The components in the 3D BIM model could be linked through the 4D scheduling model to the corresponding tasks and time, as such a visual representation of a project timeline, which again raises the probability to resolve conflicts before the construction of the project, can be represented. The project constructors can evaluate various construction options off the job site with the 3D building model linked with schedule. The schedule created in Revit can be saved as views, and can also be exported for other purposes. For instance, the schedule of Windows is exported into Excel for the manufacturer because sometimes they don't need drawings.



Family: 2 HM Frame Door with lite
Type: 36" x 84" with 4" x 2' 0" lite

Type Parameters:

Parameter	Value
Construction	
Wall Closure	By host
Construction Type	
Dimensions	
Lite Width	0' 4"
Lite Height	2' 0"
Thickness	0' 1 3/4"
Height	7' 0"
Width	3' 0"
Rough Width	
Rough Height	
Identity Data	
Assembly Code	C1020
Keynote	
Model	
Manufacturer	
Type Comments	
URL	
Description	
Assembly Description	Interior Doors
Type Mark	94
Fire Rating	
Cost	

Figure 6.Door properties in Revit (adapted from [26])

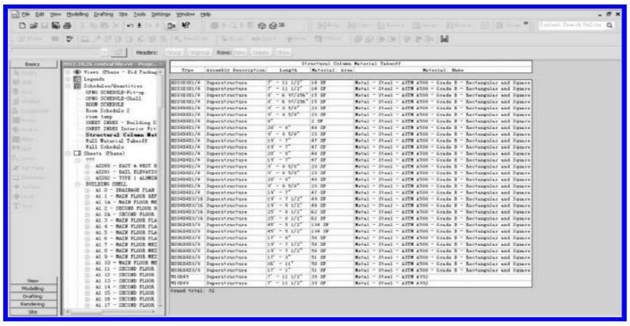
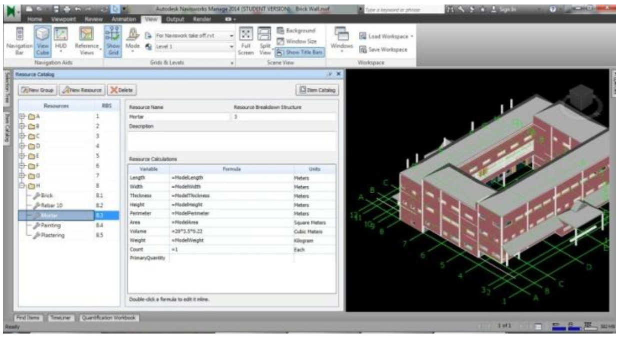


Figure 7. Part of column materials take-offs (adapted from [26])

2.5.2 Calculating materials take-off, duration and cost needed through Naviswork Manage

Mohandes S.R, et. al[11]conducted a research so as to compare three most common types of partition walls in terms of materials, time and cost needed to installeach of thembased on a case study using BIM software namely Revit Architecture and Naviswork Manage. The authors modeled the different steps involved in the installation of existing partitions namely block, brick and drywall through Revit Architecture as the first step. Then, the amount of materials needed to install each partition was calculated using Naviswork Manage 2014 as can be seen in Fig. 8. In the next step, the total duration and expenses required for installing the three mentioned partition walls were automatically calculated using Naviswork Manage 2014 (See Fig. 9).



Resources	RBS
A	1
B	2
C	3
D	4
E	5
F	6
G	7
H	8
Brick	8.1
Rebar 10	8.2
Mortar	8.3
Painting	8.4
Plastering	8.5

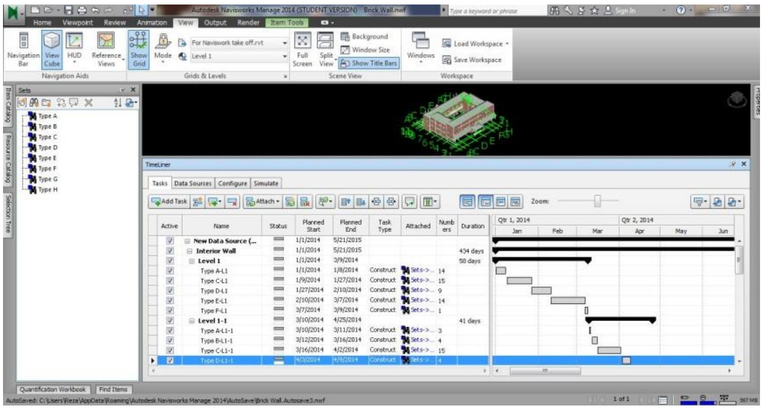
Resource Name: Mortar
Resource Breakdown Structure: 3
Description:

Resource Calculations

Variable	Formula	Units
Length	=ModelLength	Meters
Width	=ModelWidth	Meters
Thickness	=ModelThickness	Meters
Height	=ModelHeight	Meters
Perimeter	=ModelPerimeter	Meters
Area	=ModelArea	Square Meters
Volume	=20*3.5*0.22	Cubic Meters
Weight	=ModelWeight	Kilogram
Count	=1	Each
PrimaryQuantity		

Double-click a formula to edit it inline.

Figure 8. Identifying specifications for block Partitions in Naviswork Manage 2014 (adapted from [11])



Active	Name	Status	Planned Start	Planned End	Task Type	Attached	Numbers	Duration
☑	**New Data Source (...**		1/1/2014	5/21/2015				
☑	**Interior Wall**		1/1/2014	5/21/2015				434 days
☑	**Level 1**		1/1/2014	3/9/2014				58 days
☑	Type A-L1		1/1/2014	1/8/2014	Construct	Sets->...	14	
☑	Type C-L1		1/9/2014	1/27/2014	Construct	Sets->...	15	
☑	Type D-L1		1/27/2014	2/10/2014	Construct	Sets->...	9	
☑	Type E-L1		2/10/2014	3/7/2014	Construct	Sets->...	14	
☑	Type F-L1		3/7/2014	3/9/2014	Construct	Sets->...	1	
☑	**Level 1-1**		3/10/2014	4/25/2014				41 days
☑	Type A-L1-1		3/10/2014	3/11/2014	Construct	Sets->...	3	
☑	Type B-L1-1		3/12/2014	3/16/2014	Construct	Sets->...	4	
☑	Type C-L1-1		3/16/2014	4/2/2014	Construct	Sets->...	15	
☑	Type D-L1-1		4/3/2014	4/9/2014	Construct	Sets->...	4	

Figure 9. Time Calculation for block partition walls in Naviswork Manage 2014 (adapted from [11])

III. Discussion

From the review of prevailing BIM studies discussed above, several observations can be made. First, the main reason why estimators do not tend to trust the BIM QTO lies in the fact that there is no automatic method for validating the information contained in a model. A method for model checking the information is one of the most important BIM needs to most effectively advance the industry [27]. There must first be a standard for the information required for input by stakeholders at each level of model development prior to developing a validated model information. Second, it is found that although some hindrances exist in the application of BIM in building projects such as lack of training/understanding to use and lack of Standards/Software incompatibility and so forth, to name but a few, the adoption of BIM would be the most efficient and suitable way to achieve project goals. Professionals can quickly evaluate design schemes; make the right decisions at an early project stage, and efficiently cooperate with the organizations involved using BIM. The advantages of this highly advanced technology can also benefit the cradle to the grave project's cycle [7- 12 and 26]. As such, despite the fact that BIM adoption imposes extra expenses at the early stage of construction, the benefits arising from its implementation from the cradle to the grave projects' cycle considerably outweigh the expenses incurred.

IV. Conclusion

Construction is an evolving and multi-million-dollar industry which attracts numerous practitioners comprising architects, civil engineers, contractors, lawyers, suppliers and so forth to invest in. Despite the recent improvement made in diverse methods of technology used in construction industry, the management of projects is becoming excruciatingly sophisticated stemming from the staggering increase in errors occurring during a wide variety of stages of projects. With this in mind, Building Information Modeling (BIM) has recently grabbed myriad experts' attentions in the field of construction due to its interoperability feature throughout the whole lifecycle of construction projects particularly during the 4th and 5th dimensions. Although quite relatively a high number of studies have been undertaken with the aim of indicating the usefulness of BIM adoption in reducing the total duration and expenses needed to finish projects, there is a lack of comprehensive literature taking into consideration deeply the practicability of BIM in the mentioned areas. Thus, the main emphasis has been placed on the determination of how BIM utilization could provide benefits to project managers and cost estimators on the basis of past studies carried out.As far as the authors of this paper are concerned, two major observations can be made with regard to the numerous records of past research. First, lack of an existed method in order to check and validate the information given is a stumbling block for estimators to utilizing BIM. It is believed that there is a necessity of the existence of a standard for the information required as an input prior to developing validated model information. Second, no one can condone the usefulness of exploiting BIM during the diverse phases of construction, in particular 4th and 5th dimensions, in spite of its relatively high initial investment. That is to say, looking at the considerable decrease in the completion time and cost of projects could easily justifythe expenses incurred at the initial stage of construction projects.

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