A Critical Literature Review on "Building Information Modeling (BIM) - Based Dynamic Inventory Control Model for Material Management in Construction Industry"

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Abstract : Building information modeling (BIM) is one of the most promising recent developments in the construction industry. With BIM technology, an accurate virtual model of a building is digitally constructed. This model, known as a Building Information Model, can be used for each phases (Pre-Construction, Construction and Post-Construction) of project. Cost of construction material sum up-to 40-60 % of the total project Cost that's why optimization of material will control overall project cost directly. The application of inventory management techniques along with BIM technology, may give effective control on inventory and there by its cost. In this Review paper, Literature review related to the BIM technology and Inventory Management Techniques are carried out and at last Research Gap is found.

***IndexTerms* - Building Information Modelling (BIM), 3D, 4D, Inventory Management, Optimization**

I. INTRODUCTION

In the construction projects, construction managers face many problems such as over budget projects, schedule errors, omission of some activities like safety tasks that originate from poor planning methods. The traditional way of planning is done by using 2D drawings, sketches, Gantt charts, forecasts, etc., and information from several disciplines needs to be included in the schedule. Traditional scheduling methods show dependencies between activities but they do not connect the tree dimensions of space with aspects of time. Information of space and time is closely related and important for planning, evaluation, monitoring, and coordination of the construction process. The scheduler now has to make some choices earlier based on more refined decisions. Creating this link between space and time is one of the visions with BIM and referred to as the fourth dimension of CAD. The main idea is to connect activities in the time plan to objects in the 3D model, enabling visual simulations of the building process by hiding and revealing objects in a sequential order. The visualized 4D models can help managers make decisions about different method alternatives, and since every object can be coded with information such as size, material, required workforce and equipment, they can be used to make time plans, material delivery plans, purchasing schedules, etc. That should drive the development and adoption of 4D BIM.

Construction industry is second largest industry in the world after the agriculture industry. According to statistics, construction materials generally consume about 40 percent to 60 percent of total budget of the project. Therefore, it is necessary and important to properly manage and control construction materials. Currently, many inventory management techniques are used in the markets which required accurate quantity take-off. Manual quantity take off is time consumable process and chances of errors are more in manual quantity take-off processes. Yet, there is still a need to have systematic procedures and tools to comprehensively perform the challenging task of managing and optimizing material purchasing and inventory control in construction projects.

Integration of the BIM model with those inventory management techniques will gives more visualization for optimal solution in the field of material management and it improves decision. This integration also gives an idea about price escalation and quantity discount at a minimum inventory.

II. CRITICAL LITERATURE REVIEW

a) BIM

i) APPLICATION OF BIM

Isikdag et al. (2015) argues that a building information model can be used for the Existing conditions modeling, LEED evaluation, Cost estimation, Code validation, Phase planning, 3D coordination, Programming, Site utilization planning, Site analysis, Construction system design, Design reviews, Digital fabrication, Design authoring, 3D control and planning, Structural analysis, Record model, Lighting analysis, Maintenance scheduling, Energy analysis, Building system analysis, Mechanical analysis, Asset management, Other engineering analysis, Space management and tracking. **[16]**

ii) BENEFITS AND BARRIERS OF BIM IMPLEMENTATION

Redmond et al., (2012) reveal that BIM can be applied into numerous numbers of dimensions such as three dimensional modeling (3D), construction scheduling and sequencing (4D), costing (5D), sustainability (6D) and as-built modeling for facilities operations and maintenance (7D). **[24]**

Eastman et al., (2011) argue that BIM is a proven tool for the integration of design-Construction. Some of the benefits that Architects teaming with Contractors are early identification of long lead-time items, value engineering as BIM based designing process provides automate material take-off and costing and sharing BIM and better visualization assist better analysis for fabrication and detailing. And stakeholders can easily represent design intent to the Client by use of the BIM**. [4]**

Stanford University Center for Integrated Facilities Engineering (CIFE) figures based on 32 major projects using BIM indicates benefits such as **(Ju Gao and Martin Fischer, 2008) [19]**

- Up to 40% elimination of unbudgeted change
- Cost estimation accuracy within 3%
- Up to 80% reduction in time taken to generate a cost estimate.
- A savings of up to 10% of the contract value through clash detections.
- Up to 7% reduction in project time.

Caroline T. W. Chan (2014) carried out questionnaire survey and derived barriers in implementation of BIM i.e. Lack of qualified in house staff, lack of training / education and lack of standards were the most significant barriers to BIM adoption; and also Lack of client demand and lack of government's lead were the next two critical barriers. [8] Shijing Liu et al. (2015) revealed that the critical barriers are the high cost of application, lack of national standards, and lack of skilled personnel. **[26]**

iii) LEVEL OF DEVELOPMENT (LOD)

LOD is sometimes interpreted as Level of Detail rather than Level of Development, but there are important differences. Level of Detail refers to how much detail is included in the model components. Level of Development is the degree to which the component's geometry and attached information has been thought through the degree to which project team members may rely on the information when using the model (http://bimforum.org/wpcontent/uploads/2013/08/2013LODSpecification.pdf). **[31]**

Aryani Ahmad Latiffi et al. (2015) revealed that the implementation of level of detail (LOD) is varied depending on the requirements of construction players. From the use of LOD, it helps construction players to get the information that they need for a specific purpose in various project phases. The use of LOD in projects using BIM shows the capability and the level of understanding of construction players in using BIM. **[5]**

Vachara Peansupap et al. (2014) showed that the preparation of a Building Information model for cost estimation should focus on the formation of a 3D model and the level of information that is required. And also 3D model influences the quantity of work, while the level of information affects the quantity takeoff and unit cost. In addition, the estimations for material purchases require more detailed information than do estimations for bidding. Thus, the implementation of BIM through a project's life-cycle should take into account the information that can support each work operation. **[27]**

iv) QUANTIFICATION WITH BIM

Jian Li1 et al. (2014) gives quantifiable suggestions from a comparison study 'Shanghai Disaster Recovery Centre'. They revealed that construction materials costs management should primarily be based on 'quantity'; BIM can provide for accurate materials usage. With precise amounts of materials data, project managers can accurately audit for materials' procurement, issuing quantity limits, and timely changes of certificates, in order to reduce costs and improve efficiency. **[18]**

v) 4D-BIM (TIME)

Dung Thi Phuong Dang et al. (2012) identified six major benefits of 4D modeling for construction planning after reviewing the case studies : Better visualization of construction work ; More accurate and detailed work plan; Efficient planning; Better communication; Planning of temporary structures and works; Accurate quantities takeoff and Site Logistics. Then they also identified shortcomings of 4D modeling i.e. development of 4D model from 2D documents is a timely and challenging task; requires highly skilled and trained staff to execute the process; the change of construction sequence of bridge due to several engineering problems did not lead to updating of the 4D model; transforming the results from 4D simulation to strategic information is a laborious task. [13] Mr. Abhimanyu Basu et al. (2007) summarized the important current scheduling practices which are not supported by 4D modeling i.e. Procurement and Offsite Activities; Critical Path, Late Dates and Float; Cost, Resources and Earned Value**. [22]**

vi) CLASH DETECTION

Wang Guangbin (2011) revealed that clash detection checks models from all disciplines (architectural, structural, mechanical, electrical, plumbing, etc.) against each other for interference. This allows designers to create a more efficient design that dramatically reduces costly changes in the field, wasted spaces in plenums and mechanical rooms. Also, it helps constructors to accurately take-off a building and sequence the construction more easily. The conflicts are detected in the computer before construction starts, and therefore speed the construction schedule, reduce costs and change orders. The productivity of design and construction are improved accordingly. **[28]**

Bhamre Gaurav Shyamkant et al. (2017) listed out the three types of clashes as follow:

- Hard Clash: when two objects pass through each other. Most BIM modeling software eliminates the likelihood for this using clash detection rules based on embedded object data.
- Soft Clash: work to detect clashes which occur when objects encroach into geometric tolerances for other objects (for example, a building being modeled too close to a high tension wire).
- 4D/Workflow Clash: clash resolves scheduling clashes and abnormalities as well as delivery clashes (for example, work crews arriving when there is no equipment on site) **[7]**

Anderson O. Akponeware et al. (2017) summarized causes of hard and soft geometric clashes in a BIM model as follow: Use of wrong or low level of detail; Design uncertainty/use of Placeholders; Failing of design rules; Accuracy versus deadline; 3D model objects exceeding allowable clearance; Designers working in isolation from each other; Design complexity; Insufficient time; Use of 2D instead of 3D models; Design errors; Use of different file formats Lack of experts. And also summarized clash avoidance strategies by various researchers as follow:

Impose BIM in traditional procurement, Integrating Engineering, Construction and Procurement, Improvement in software detection algorithms, Co-creation among designers in a shared workspace, Designers working with more information provided by other specialists, Designers being more careful/accurate with their own model output, Design coordination in a common data environment (CDE), Shared situational awareness. **[3]**

b) INVENTORY MANAGEMENT

Darya Plinere et al. (2015) revealed that inventory management is essential to every company, having inventories. Companies need to have stock, but in such amount to avoid out-of-stock and overstock situations. Inventory management can improve company's inventory control existing situation and decrease costs of the company. Also they concluded that timely reaction to changes in the environment can propose better results. **[9]**

James Lanman (2005) reveals that inventory control techniques represent the operational aspect of inventory management and help realize the objectives of inventory management and control. The techniques most commonly used are the following: ABC Analysis, HML, VED, SDE, FSN, S-OS, XYZ, GOLF, EOQ, Minimum-Maximum, Two Bin Techniques. **[17]**

i) ABC ANALYSIS

Fariborz .Y. Partovi et al. (2002) shows, ABC analysis is one of the most commonly employed inventory classification techniques. Conventional ABC classification was developed for use by General Electric during the 1950s. The classification scheme is based on the Pareto principle, or the 80/20 rule, that employs the following rule of thumb: "vital few and trivial many. "The process of ABC analysis classifies inventory items into A, B or C categories based on so-called annual dollar usage. Annual dollar usage is calculated by multiplying the dollar value per unit by the annual usage rate**" [14]**

Yogesh kumar et al. (2016) shows necessary steps for ABC analysis as follow:

- Prepare the list of items and calculate their unit price, annual consumption,
- Arrange items in the decreasing of their annual usage.
- Calculate percentage of annual usage, cumulative of annual usage and then categories the inventory item.
- Plot the graph on the basis of cumulative of annual usage and then categories the inventory items**. [30]**

T. Phani Madhavi et al. (2013) listed out advantages of ABC Analysis as follow:

- The inventory control of different categories of items will be better if costlier items are not stored for large period, which reduces capital investment.
- The quantities of various categories of items are economically ordered and stored as per need. It saves the cost of ordering and carrying the inventories.

- The purchasing of various categories of items becomes easy and discounts are also obtained on large purchase of items of C category.
- Better record keeping of different categories of items helps in good inventory control. **[27]**

ii) ECONOMIC ORDER QUANTITY

Dr. Rakesh Kumar (2016) revealed that inventories are assets of the firm, and as such they represent an investment. Because such investment requires a commitment of funds, therefore a firm has to maintain inventories at the correct level. If they become too large, the firm loses the opportunity to employ those funds more effectively. Similarly, if they are too small, the firm may lose sales. Thus, there is an optimal level of inventories. The EOQ is a model that is used to calculate the optimal quantity that can be purchased to minimize the cost of both the carrying inventory and the processing of purchase orders. **[12]**

Aju Mathew et al. (2013) concluded that the economic order quantity is, optimized the order quantity for each product when an order is placed, reducing the company's product stock out issue. By providing and recommending the inventory control model, the results have shown improvements in forecasting as well as in cost reduction. So, if the company follows through and implements the recommended inventory model, they would be able to reduce the total cost by approximately 20% which is a cost reduction of for top selling products. **[2]**

Dr. Angel Raphella. S et al. (2014) shows that the ABC analysis technique for the inventory control system is first used to identify the most important multiple products and then the economic order quantity (EOQ) of each product is developed to find their inventory model equation individually**. [11]**

iii) REQUIREMENT, IMPORTANCE AND BENEFITS OF INVENTORY MANAGEMENT

M. Leseure, (2010) mentions several reasons why it is needed to have inventories:

- To meet anticipated demand;
- To smooth production requirements;
- To protect against stock-outs;
- To take advantage of order cycles;
- To hedge against price increases or to take advantage of quantity discounts;
- To permit operations;
- To decouple components of the production-distribution system. **[21]**

Jyoti Sanjeev Mohopadkar et al (2017) listed out the importance of inventory management are as follow:

- To economize on buying/manufacturing cost
- To keep pace with changing market conditions
- To satisfy demand during period of replenishment
- To take care of contingencies
- To stabilize Production
- To prevent loss of sale **[20]**

Ashwini R. Patil et al. (2013) revealed that an effective material management system can bring following benefits

- Reducing the overall costs of material
- Better handling of material
- Reduction in duplicated orders
- Material is on site when needed and in the quantities required
- Improvements in labor productivity
- Improvements in project schedule
- Quality control
- Better field material control
- Better relations with suppliers **[6]**

c) INTEGRATION OF BIM AND INVENTORY MANAGEMENT

Simaan AbouRizk et al. (2010) argue that construction simulation is the science of developing and experimenting with computer based representations of construction systems to understand their underlying behavior and he defined areas of application where simulation is generally more effective than other tools in the following situation:

- When problems are characterized by uncertainty
- When problems are technically or methodically complex
- When repetition is evident

- When flexibility in modeling logic and knowledge is required to formulate a model
- When an integrated solution is required
- When detail and accuracy matter **[25]**

Dennis F. McCahill et al. (1994) created a model that allows construction-process simulation to be conducted in a simple fashion, in the field, oriented to the attributes of the specific resources available for the process and argue that in modeling for simulation, the proper representation of crucial real-world variables in the model is of prime importance. And show that it can serve as a useful step in realizing the objective of achieving more realistic response and significant simplification of construction simulation, both in the performance of the system and in the user interface. Potential improvements could include the addition of graphic model displays and a method to allow minor variations in the models by the user. Also beneficial would be quicker editing, and the extension of the program for the analysis of large projects with many earthwork operations. **[10]**

Gokhan Gelisen et al. (2010) developed Automated Productivity-Based Schedule Animation (APBSA) tool. This is a dynamic scheduling methodology that stochastically utilizes weekly trended construction labor productivity data in order to automatically update the baseline schedule that was created at the beginning of the project by the construction manager. APBSA reports the construction activity duration variances and animates the progress of the job with most current data available in a four-dimensional (4D) environment. And they revealed that contractors can improve their planning by utilizing APBSA with building information modeling (BIM) which will help them to improve their craft productivity. **[15]**

Aijuan Zou et al. (2012) carried out optimization research of construction Inventory based on Inventory Theory. He concluded that at present, the trend of contractor inventory management is to achieve "zero" inventory of material. If contractors want to achieve "zero" inventory management, they should carry out dynamic management of purchase which is based on supply chain management in the purchase management of project. And this requires all parties involved establish cooperation relationship, achieve information and resource sharing, take the same responsibility and share interest together to eliminate the influence that demand fluctuation of material. **[1]**

Qunzhou Yua et al. (2016) developed BIM based dynamic model for material supply and introduced the implementation process of the optimal supply scheme by a case study. They concluded that BIM technology is introduced into the construction site material supply management, the establishment of dynamic model, which validates the value of BIM in the field of material supply management; Material quantity, delivery time and storage area are combined to achieve the integration of multiple information; 4D application ensures the timely scheme generation of the whole process, which helps the project participants to better solve the site material supply problem. Also from case study they reveal that the implementation of the model can reduce the rate of repositioning by 90% and increase construction efficiency by 20%. **[23]**

III. CONCLUSION

As per above literature review, no research work found that gives a BIM based dynamic inventory control model. There are vast benefits of the BIM in different application areas. Some researcher gives an idea about the inventory control models to optimize the inventory cost but they did not suggest any idea about accurate quantification of those inventories. And some researcher gives BIM based dynamic material supply model based on the material quantity, delivery time and storage area only. They did not consider any cost criteria related to inventory management. So research gap found between the BIM Technology and Inventory Management Techniques. To fill that gap research work is carried out for “Building Information Modeling-BIM Based Dynamic Inventory Control Model for Inventory Management in Construction Industry.”

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