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BIM Based Inventory Management in Construction of Residential Highrise Building in India

Aditya Mahajan and Anil Kumar Chilakapati
School of Planning and Architecture, Vijayawada, Andhra Pradesh, India
E-mail: 1210900044@spav.edu.in, anilkumarchilakapati@gmail.com

Abstract - **According to a study, construction materials account for more than 65 percent of a project's entire cost. Material Planning efficiency is critical to completing a project on scheduled time and on budget. This research paper focuses primarily on inventory control and materials planning using BIM process as this are the important pillars of material management. The S-curve analysis is used to determine how much the estimated materials cost differs from the market materials cost. Engineers and contractors are interviewed to determine the main reasons for this. Inventory management techniques such as ABC classification and economic order quantity (EOQ) analysis are performed. In most cases, S-curve analysis shows that actual material costs are greater than estimated material costs. BIM-based ABC and EOQ analyses are used to continuously maintain sufficient inventory, protect inventory materials from damage, reduce inventory costs, solve inventory problems, and maintain optimal inventory levels. A sensitivity check is applied to the results of the EOQ analysis. "The use of ABC classification and EOQ analysis can help to alleviate the stock-out of A class and B class materials that occur on building sites. Following the implementation of these easy inventory control strategies, the total inventory expenditure is reduced".**
Keywords: **ABC Classification, BIM, Construction Management, Material Management, Inventory, S-Curve**

I. INTRODUCTION

Material management in the construction industry is one of the important aspects, as the material cost is more than 55% of the total project cost. Without proper materials management, an organization will not be able to execute the project as planned or may face financial constraints. Proper inventory control and tracking systems help in reducing these risks. The process of supplying the appropriate quantity and quality of specified construction is described as material management. materials on scheduled time and compliance to safety related requirements in order to construct a building. Construction material management is the planning of purchases, keeping track of inventories, storing materials with correct treatment, and moving them. Material inventory techniques are very effective in improving the utilization of raw materials, which ultimately reduces the cost of such materials for the company.

Modern construction material management relies on accurate information. Large construction businesses are the main users of material management software including EAM brace inventory management, NEESA material management system, and spine BMS. Smaller construction companies, however, rely on trained workers and contractors. Finding a solution for small- and medium-scale projects is the main goal of the research.

A. Context

Previous studies shows that a huge amount of investment is incurred in Material procurement and its Management. The reason behind this is lake of coordination and progress tracking in construction progress. Due to its enormous impact on project delivery, material delivery in construction is a crucial activity that demands more attention from project management teams.

Researchers have long recognised the significance of supply chain integration in the construction industry because, when done well, it can lower costs by 2.2%. (Gerard and Fisher). Supply chain, on the other hand, has its own related waste, the origin of which is often found during a different building phase than that in which it is detected. (Ruben and Koskela). So iBIM (Intelligent Building Engineering Modeling) based inventory Management can help the infrastructure and building construction Industry in India.

B. Issue

Lake of Coordination between stakeholders and vendors regarding Material Procurement of Construction Material. The size of Inventory is also an important aspect which should be taken care of, so to decrease the indirect cost of Store. Inefficient planning and scheduling & less use of BIM technology in India. Reviewing and analysis of previous workflow of Inventory Management.

C. Argument

On-site Store Management and Material management in Construction Industry. A case example is given in the literature review. I see a huge scope of saving the resources, which includes money, time and also reduces waste which ultimately helps in increasing sustainability aspects of the surroundings, optimization of all the resources and improvement in triple constraints is the solution which will be concluded in this paper.

D. Objectives of the Study

1. Reviewing comparing calculation of material quantity using BIM and Traditional method.
2. Review and compare the methods to calculate Economic Order Quantity (EOQ) using BIM.
3. ABC classification of Materials for Cost Control.
4. Compare different techniques and workflow of Inventory management.

E. Limitation

The study is limited only to inventory management during construction phase. Not included Inventory during pre and post construction phase.

II. LITERATURE REVIEW

The Author suggested in his paper, "Improving Effective Material Management by Identifying common Factors in Building Construction Project" discussed that material management has been a major challenge for construction projects for many years. The purpose of this article is to identify common building construction features in order to improve current material management. It is vital to have the right materials and time to complete a construction project. Building materials can account for more than 55 percent of a construction project's entire cost, according to this analysis. One of the most common reasons of construction project delays is poor material and equipment management. This study described some significant variables affecting good material management and inventory management based on a literature review.

In their work, "Material Management in Construction," the author, (Madhavi, and Mathew) proposed that all of the company's problems are brought on by inefficient material management. Construction project operations frequently involve project cost variance in terms of material, equipment, labour, subcontractor, overhead costs, and general condition. Materials are the most crucial element in construction projects.

The Author, V. Patel and Chetna M. Vyas attempts to fill a gap through his research in, "Construction material management on project sites" due to inefficient materials management on construction sites. A successful and economical building site requires excellent material management. According to research, the total cost of a typical construction project might be up to 70% made up of materials and equipment. Therefore, efficient management of this one key area can increase a project's productivity, cost effectiveness, and timeliness. The main conclusions of a survey of the material management of three well-known Ahmedabad builders are summarised in this report.

III. METHODOLOGY

Study first collected the materials like literature review and latest published papers related to inventory and material management, then a case study of a live construction project and circulate a survey form to the experts related to the field, and then draw the conclusion from the analysis of the case study and survey results.

A. Case Study

A Stilt+14 floor apartment building in Dodannakalli, Bangalore, was chosen as the case study for the research project. The total built up area of the building is 60,135 sqm with 32 dwelling units per floor.

B. S-Curve Analysis

A plot of cumulative cost, labour cost, or other quantities against time or other parameters is shown as an S-curve. It is a form of numerical theory that shows how much material will be used during the course of the project. The curve compares actual time and spending amounts to times and amounts projected for various resources. It is used to monitor the project's advancement. This study uses the S-Curve to analyse the cost disparity between the materials that were planned and those that were actually used. An S-curve study is carried out for some of the most important building materials, such as cement, steel, and bricks.

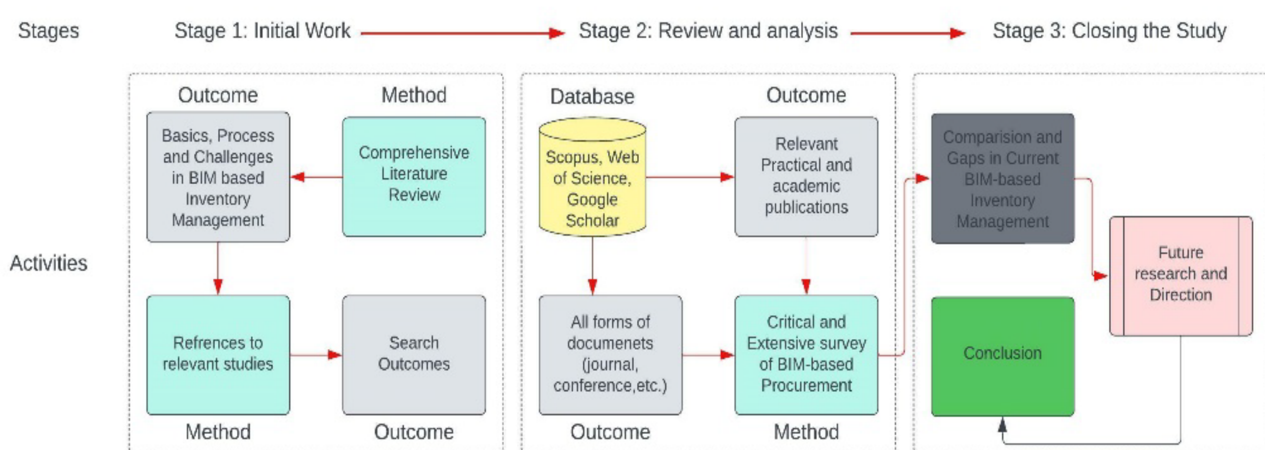

Fig. 1 Overview of Research Approach

Table I, and Table II indicate the resemblance between planned and actual material costs for cement and steel in the construction of an apartment building. The actual materials cost is clearly more than the projected materials cost calculated through BIM based software, as seen in the graphs.

The project has a cost teeming since the Cost Performance Index is less than one for all three materials. The materials management component is the same for small and large projects, despite the fact that this is a modest apartment project.

TABLE I COST PERFORMANCE INDEX OF SELF COMPACTING CONCRETE

Cost Performance Index for SCC					
Sl. No.	**Levels**	**Planned Cost through BIM based Tools (INR)**	**As-Built Cost (INR)**	**Variance (INR)**	**Cost Performance Index (CPI)**
1	Stilt	71,65,000	73,06,750	141750	0.98
2	1st Floor	81,39,750	83,21,965	182215	0.97
3	2nd Floor	77,38,200	80,79,874	341674	0.95
4	3rd Floor	78,09,850	80,66,047	256197	0.96
5	4th Floor	79,90,580	81,65,040	174460	0.97
6	5th Floor	78,54,600	80,95,500	240900	0.97
7	6th Floor	8256000	85,75,000	319000	0.96

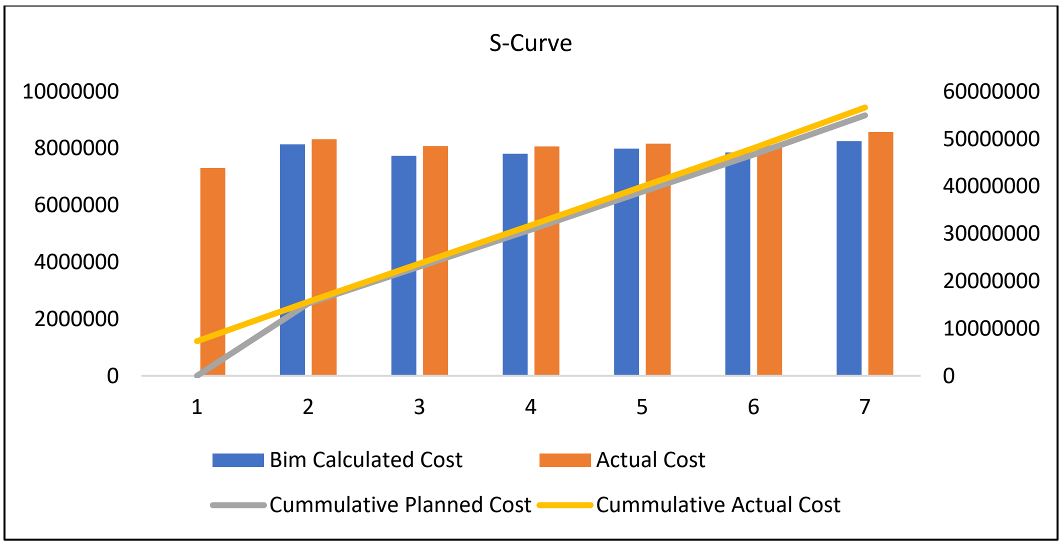

Fig. 2 S-Curve Analysis of SCC

TABLE II COST PERFORMANCE INDEX OF STEEL

Cost Performance for Steel					
Sl. No.	**Levels**	**Planned Cost through BIM based Tools (INR)**	**As-Built Cost (INR)**	**Variance (INR)**	**Cost Performance Index (CPI)**
1	Stilt	7,72,16,850	7,96,05,000	23,88,150	0.97
2	1st Floor	7,64,20,000	8,04,41,650	40,21,650	0.95
3	2nd Floor	8,34,00,600	8,59,80,000	25,79,400	0.97
4	3rd Floor	8,24,37,000	8,67,76,100	43,39,100	0.95
5	4th Floor	8,61,20,480	8,87,84,000	26,63,520	0.97
6	5th Floor	8,20,38,500	8,72,75,000	52,36,500	0.94
7	6th Floor	8,98,66,000	9,17,00,000	18,34,000	0.98

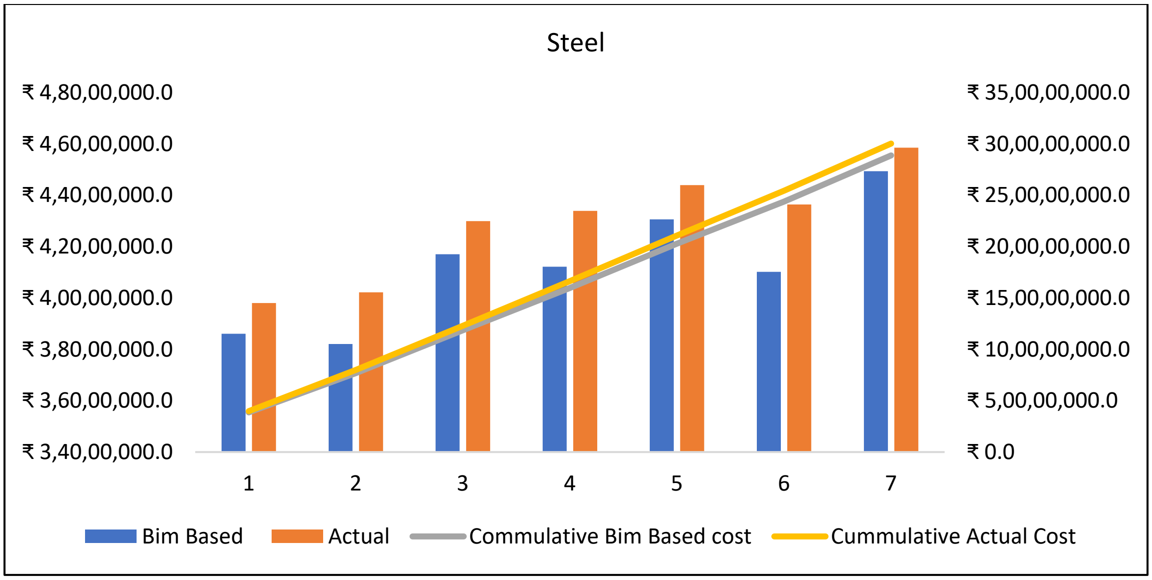

Fig. 3 S-Curve Analysis of Steel

C. Reasons for Cost Variance

The project cost can be kept under control by identifying the primary sources of cost variance and taking appropriate measures. To determine the primary sources of material cost variation. Interviews with experienced managers have been undertaken. Engineers and contractors, in particular. The most important reasons for the cost variance, which were discovered through.

D. ABC Analysis

Sorting the products into categories based on their worth and importance is an important consideration. Inventory classification enables us to identify inventory that needs specialised management and attention. Additionally, it aids in minimising waste by ensuring that resources are used effectively. The ABC analysis serves as the cornerstone for managing materials and aids in determining stocking and inventory check intervals. It's an analytical system for monitoring different inventory goods. Pareto's law states that a small number of factors account for a sizable proportion of value. All of the resources used in this analysis are divided into the following three categories: A, B, and C.

In ABC classification, the materials are classified as

1. A class material – 70% of money is assigned to 20% of the material.
2. B class material – 25% of money is assigned to 30% of the material.
3. C class material – 5% of the money is assigned to 50% of the material.

The inventory items are classified according to characteristics such as investment, material worth, and kind of inventory products. The process for performing ABC categorization is as follows.

1. The various materials needed for the construction project are identified, and estimated quantities are computed.
2. The unit rates of materials are estimated.
3. Multiplying by the estimated quantities and unit rates yields the use values for each of the materials.
4. These figures are expressed as a proportion of total annual usage or project cost.
5. The percentage utilization cost for each of the materials is listed in descending order of their rating, starting with the greatest usage value and ending with the lowest.

E. EOQ Analysis

Ordering and holding expenses are two important areas of inventory costs. Ordering costs include costs for transmitting orders, transportation, and supplier selection, among other things. The costs of keeping the list are referred to as holding costs. It covers storage, spoilage, insurance, and taxes, among other things. The expenses of ordering and carrying are diametrically opposed. Small orders should be placed to reduce carrying costs, but this increases ordering costs and vice versa. The EOQ model aids in the reduction of overall inventory expenditure.

In order to save money on both carrying inventory and processing purchase orders, the Economic Order Quantity (EOQ), a model related to inventory, is used to calculate the best quantity that can be purchased.

The formula for determining the optimum quantity is,

Q – Order quantity; number of units per order
$Q = \sqrt{(2*O*D)/(I*C)}$
O – Ordering cost; INR/order
D – Rate of demand
I – Inventory carrying cost
C – Unit cost of the material

F. Sensitivity Analysis

Sensitivity analysis is a technique for determining how sensitive an output is to changes in one or more input variables. It's frequently used to compare distinct scenarios whose outcomes are dependent on altering inputs. It's useful since it shows how dependent each input value is on the output value. The procedure for conducting sensitivity analysis is as follows.

1. Using primary input values, determine the principal output value.
2. Change one input value while keeping all other input values constant to find the new output value.
3. Calculate the percentage change in output value and percentage change in output value.
4. Determine the sensitivity by dividing the output percentage change by the input percentage change.

Given that demand and inventory holding costs are the two inputs that are most susceptible to change, the sensitivity analysis in this work is used to determine how changes in these values will impact the output value of EOQ.

The construction materials are separated into three groups using the ABC categorization method: A, B, and C. A class materials include cement, steel, bricks, sand, and aggregates, for instance. B class materials include, for instance, ceramic tiles, emulsion paint, country wood, glazed tiles, teak wood, electrical holders and fittings, PVC pipes and accessories, European water closets, and paver blocks. The remaining items are categorised as class C materials.

EOQ analysis provides recommendations for how much and how frequently to order A-class materials like cement, steel, bricks, sand, and aggregates in order to lower overall inventory costs and maintain inventory at an ideal level. According to sensitivity analysis, the sensitivity is 0.42 for a 25% change in inventory holding costs and 0.3 for a 12% change in demand.

The use of ABC classification and BOQ analysis can help reduce the stock-out of A class and B class materials that occur on building sites.

G. Survey Analysis

Following the 39-sample survey, I analysed the data from the perspectives of various professions, including Project Manager (7.7%), Architect (82.1%), Civil Engineer (7.7%), and Client (7.7%).

TABLE III SURVEY ANALYSIS RESULTS

Sl. No.	Questioners	Very High Impact	High Impact	Normal	Low Impact	Very Low
1	[Receiving incorrect material type]	33.3%	23.1%	25.6%	17.9%	0.0%
2	[Increase materials quantity in storage]	2.6%	20.5%	48.7%	20.5%	7.7%
3	[Burglary, theft and vandalism]	10.3%	43.6%	15.4%	25.6%	5.1%
4	[Destroy material in shipping]	7.7%	25.6%	35.9%	28.2%	2.6%
5	[High cost in material transportation]	12.8%	38.5%	41.0%	2.6%	5.1%
6	[Unavailable required quantity]	10.3%	41.0%	25.6%	17.9%	5.1%
7	[Too early receiving of materials earlier usage]	10.3%	38.5%	41.0%	10.3%	0.0%
8	[Incorrect material take-off from drawing and design]	23.1%	43.6%	25.6%	2.6%	5.1%
9	[Material Shortage during construction]	28.2%	30.8%	30.8%	7.7%	2.6%
10	[Piling of inventory materials]	2.6%	23.1%	51.3%	17.9%	5.1%
11	[Poor material selection]	23.1%	33.3%	17.9%	20.5%	5.1%
12	[Slow delivery materials]	10.3%	46.2%	35.9%	7.7%	0.0%
13	[Suddenly alternation price of materials]	30.8%	41.0%	17.9%	5.1%	5.1%
14	[Ineffective control of storage]	12.8%	41.0%	30.8%	12.8%	2.6%
15	[Incomplete drawing design and specification]	23.1%	41.0%	25.6%	5.1%	5.1%
16	[Poor cutting of materials (glass, tiles, plywood)]	23.1%	28.2%	38.5%	10.3%	0.0%
17	[Inadequate skill in utilization of materials]	17.9%	38.5%	20.5%	15.4%	7.7%
18	[Insufficient places for material storing]	5.1%	28.2%	41.0%	23.1%	2.6%
19	[Wrong methods and regulations in materials usage]	15.4%	35.9%	30.8%	10.3%	7.7%
20	[Poor materials storage facility]	10.3%	38.5%	35.9%	15.4%	0.0%

The article will introduce a major project that is currently being used as an example to assess what methods are best for managing inventory material in the construction industry. Strategies chosen will then be applied to another major project. The analysis will target key metrics such as: total cost savings, time savings, accuracy improvement, improved productivity and efficiency at actual operation levels.

IV. RESULTS AND DISCUSSION

Following the implementation of BIM based ABC and EOQ analysis, the overall cost of inventory is found to be lower. The results of the S-Curve analysis show that there are differences between the costs of planned and actual materials. The graphs demonstrate that the actual cost of the materials is greater than the projected cost. When the Cost Performance Index for each material is determined, it supports the conclusions of the S-curve study since it demonstrates that cost overruns occur when the index is less than one.

The reasons for the discrepancy between planned and actual material costs are found to be poor scheduling and estimation, poor forecasting of market and field conditions, a lack of materials, damage from transportation and storage, poor material utilisation planning, client intervention, and changes in legal and economic conditions. The results show that the materials cost overrun is a result of both internal and external factors.

V. CONCLUSION

Each project has its own material mix. This mix may differ for different projects and different time frames. Even on the same project, different parts of the site may require varying amounts of material at a given time. However, it is much more difficult to manage the resource through combining materials so that they are used when they are needed and in an efficient manner, especially when large quantities of material are involved. In this study, resources were used and measured in both production and inventory form. The main objective was to measure the use and cost-effectiveness of some products through a practical and technical approach. According to a study, employing appropriate material management enhanced the project's overall efficiency by 25 percent. This project effort proposes some simple technologies for efficient material management. The S-curve analysis is used to highlight the difference between planned and actual material costs. The primary cause of this variation has been found. Contractors and engineers can enhance their material planning and keep total project costs under control by concentrating on these issues. To avoid stock outs and lower total inventory costs, ABC categorization and EOQ analysis are utilised using BIM technology.

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