Inventory Management In Construction Using Value Stream Mapping And Stochastic Models

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Abstract- *Researchers have long been trying to implement supply chain management practices in the construction industry after its successful implementation to the manufacturing industry. The construction industry, however, is highly fragmented, does not have a uniform workflow and its efficiency largely depends upon the site conditions where the construction process is carried out. These factors make the application of Supply chain management practices to the construction industry difficult. However, due to the completion of most processes in the factory like environment, prefabricated buildings have a striking resemblance to manufacturing. This research intends to apply supply chain management practices to the construction process of a single-story prefabricated steel structure. Based on classic stochastic inventory models the economic batch quantity for each of the steel elements involved in the construction is calculated. Based on this a new inventory management system is proposed. The present inventory management practices are mapped to calculate the total inventory cost, which is then compared with the total inventory cost estimate of the proposed system. Results depicted an overall reduction in the lead time of fabrication and savings in the total inventory cost by applying the proposed inventory management system.*

Keywords- Supply chain management, Prefabricated buildings, Value stream, Workflow, Inventory management, Economic batch quantity

I. INTRODUCTION

Construction Industry is one of the fastest expanding industries in the world and finds its presence in all sectors of the economy. This industry's contribution to global GDP is roughly one - tenth of the total amount [1]. The infrastructure spending in construction sector as a part of India's GDP rose from 6.4 percent in 2008 to 9 percent in 2017. The Indian construction industry is expected to grow at a compound annual growth rate (CAGR) of 15.7 % to reach 738.5 billion USD by 2022.

Amidst this staggering growth, the construction industry is plagued by low efficiency and productivity. Lagging construction productivity costs the global economy 1.6 trillion USD per year [2]. Construction management is the discipline, which aims at solving this problem. Over the years various methodologies have evolved in this area which includes critical path method (CPM), project evaluation review technique (PERT), Lean Construction management (LCM), value stream mapping (VSM), Integrated Project delivery (IPD) etc. Construction supply chain management (CSCM) is an ongoing area of research in construction management.

Supply chain management (SCM) was first applied in the manufacturing sector. Just-In-Time (JIT) delivery system used in Toyota Production System (TPS) showed the first signs of SCM in manufacturing industry. In TPS, value stream mapping is used to identify the non-value adding activities and eventually eliminate or reduce them [3]. Sustainable supply chain management (SSCM), which involves integrating environmental, social and economic goals of a firm's SCM process [4].

Although, the concept of SCM originates from the manufacturing industry, construction industry can also benefit from such best practices [5]. The uniqueness of each project and prevalence of fragmentation in construction process makes the construction supply chain different from production supply chain. In construction, all the processes from production to installation takes place at site and depend on the physical conditions such as soil and weather conditions [6].

II. CONSTRUCTION SUPPLY CHAIN MANAGEMENT(CSCM)

SCM in construction is defined as "the network of facilities and activities that provide customer and economic value to the functions of design development, contract management, service and material procurement, materials manufacture and delivery, and facilities management" [7]. Implementation of CSCM offers new approaches to new approaches to reduce the cost , accelerate construction and increase reliability [8].

Construction supply chain is essentially a make to order supply chain i.e., construction starts once the order is placed [9]. Development issues faced are information transparency, reduction in variability, synchronizing of material flows, management of critical resources and configuration of supply chain. Four roles of supply chain management in construction include improving the interface between site activities and supply chain, improving the supply chain, transferring activities from the site to the supply chain and integrating site and supply chain [9].

The performance of the entire supply chain is affected by four major drivers: inventory, transportation, facilities and information. Three major drivers - transport, facilities and information - are closely related to inventory. With the objective of lowering the inventory level, decisions are taken to determine the values of these other major drivers.

Inventory is the main source of cost in the supply chain and is generated when the production and supply activities of a supplier do not correspond perfectly to the demand of buyers. It is common in the construction industry for large quantities of construction materials to be stored at a construction site or manufacturing plant because contractors or manufacturers want to procure or supply these materials before they are actually required. This additional inventory entails additional inventory costs and causes serious construction problems, such as site congestion and, in some cases, material quality deterioration.

In order to reduce the problem of the inventory of construction materials the concept of integrated inventory is adopted with an aim of optimizing the inventory cost both at construction sites and production facilities. This creates a win–win situation for both the buyers and the suppliers [12]

III. METHODOLOGY

The methodology of the project consists of three different aspects which aim at optimizing the costs involved in the inventory management of steel as well as the demand control of steel for a company named 'Agrima Constriction Curators', which is good source of steel producers for several construction projects. The two main aspects are: Forecasting and Economic Batch Quantity.

A. Forecasting

Based on the amount of steel used previously the need for steel for the upcoming days is determined. This helps in predicting the quantity of steel for a particular period. Hence, a significant amount of steel for that particular period can be brought in. This helps in saving inventory costs by not storing additional steel in the inventory or storage areas.

B. Economic Batch Quantity

Economic Batch Quantity is the modified EOQ model. This model suggests both production and consumption of steel plates simultaneously. EBQ model also orders steel at regular intervals but consumption starts after inventory reaches some level. An advantage of EBQ model is that EBQ can be applied on more than two different elements simultaneously. Hence, all the required elements are produced and consumed simultaneously saving inventory costs and speeding up the process.

IV. RESULTS AND DISCUSSIONS

A. Forecasting

Exponential Smoothening is a time series forecasting method for a single variable or quantity. Unlike simple average which assigns equal weights to all the observations, Exponential smoothening assigns higher weightage to the latest observation and then exponentially decreasing weights to the previous observations. This model introduces to a new parameter "□", which is known as a smoothing factor or smoothing coefficient. The value of □ ranges from 0 < □ < 1. If the more recent values help to determine the forecast then □ is closer to 1 and if the previous forecasts have more influence in determining the forecast then □ is closer to 0. The general equation for the exponential smoothening model is shown below. This model uses all the demand values from the previous data and assigns progressively decreasing weights from the most recent values to the past values.

$$F_{t+1} = \alpha D_t + (1-\alpha) F_t$$

Where, F_{t+1} is the forecast for the period t + 1;
D_t is the demand value for the period t;
F_t is the forecast value for the period t;
and $0 < \alpha < 1$

Weekly Demand	$\alpha = 0.5$	$\alpha = 0.6$	$\alpha = 0.7$	$\alpha = 0.8$
1984.44	1014.588	1100.594	1175.813	1240.835
4303.34	3865.716	4045.074	4179.954	4290.184
4489.05	4253.548	4215.141	4160.287	4097.209
5426.7	3993.676	3996.704	3997.498	3988.182

Table 4.1: Weekly forecasting value for different values of α.

B. Economic Batch Quantity (EBQ) Model

EBQ model is followed when production and consumption takes simultaneously place at the site. In this research, EBQ model had been applied to the fabrication and installation of steel elements including columns, jack beams and rafters. Fabrication and installation was considered equivalent to production and consumption respectively. From the data collected at the site, the current production-consumption model was plotted as shown in figure 4.1**.** In the figure traces 0,1 and 2 represent columns, jack beams and rafters. This was followed by the calculation of total inventory cost of the current production-consumption model. For the calculation of total inventory cost, area under the curve for each type of element and the total setup cost was calculated. Since, all types of elements required same setup, the applied for single setup case. Using the economic batch quantity model the EBQ for each of the elements were as shown in table 4.2.

Table 4.2: EBQ for different elements

Elements	Cycle Time (days)	EBQ (numbers)
Columns	21	11
Jack Beams	21	8
Rafters	21	17

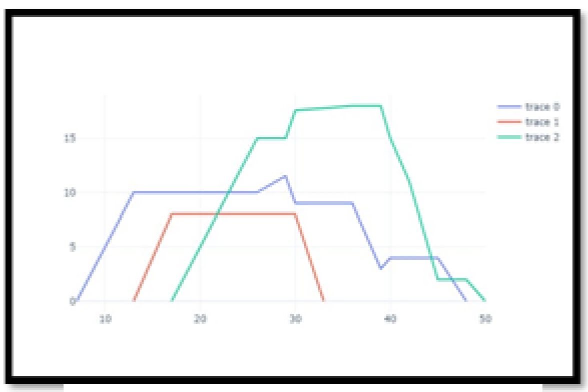

Figure 4.1: Present inventory model

V. CONCLUSIONS

Based on the results and discussions, conclusions can be drawn on forecasting model and EBQ model.

A. Forecasting

The forecasted values show less deviation from the actual data in the 2nd and 3rd week, while it shows large variations in the 1st and 4th weeks. After interviewing the site engineers it was determined that due the installation and removal of setup in the initial and final weeks respectively the forecasted values showed large variations.

B. Economic Batch Quantity Model

The project required the production of 23 columns, 8 Jack beams and 35 rafters in a period of 43 days. Based on the data available from value stream mapping and demand control, the maximum production rate is determined as 2.11 units per day. The proposed EBQ model satisfies the producation rate. Also, the present model costs Rs. 14,063.76 while the proposed model costs Rs. 10,964.22. Hence, the total cost saviings is Rs. 3099.54. Hence, 22% of the total costs on inventory is saved.

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