Study on Optimized Material Procurement and Storage In Construction

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Abstract

Efficient planning of materials procurement and storage on construction sites can lead to significant improvements in construction productivity and project profitability. Existing research studies focus on material procurement and storage layout as two separate planning tasks without considering their critical and mutual interdependencies. The present work reports the development of a new optimization model for construction logistics planning that is capable of simultaneously integrating and optimizing the critical planning decisions of material procurement and material storage on construction sites. The model utilizes EOQ to minimize construction logistics costs that cover material ordering, financing, stock-out, and layout costs. The model incorporates newly developed algorithms to estimate the impact of potential material shortages on-site because of late delivery on project delays and stock-out costs.

Keywords: construction logistic cost, storage area planning, price breaks, planned shortages.

1. Introduction

Material procurement and storage on construction sites need to be properly planned and executed to avoid the negative impacts of material shortage or excessive material inventory on-site. Deficiencies in the supply and flow of construction material were often cited as major causes of productivity degradation and financial losses. Ordering smaller quantities of material more frequently minimizes the locked-up capital in material inventories; however, it increases the probability of material shortages and project delays. On the other hand, ordering larger quantities of material less frequently minimizes the probability of material shortage and project delays; however, it increases the cost of locked-up capital in large inventory buffers on-site. Construction planners need to consider this critical tradeoff during the planning of material procurement and storage on-site.

A number of research studies were conducted to investigate the procurement and storage of construction material on-site. Hence the construction logistic planning (CLP) model is adopted because which has interdependencies between the procurement decisions and storage areas. The details of the construction logistic cost is explained below

1.1 Purchase Cost

This refers to the nominal cost of inventory. It is the purchase price for the items that are bought from outside sources, and the production cost if the items are produced within the organization. This may be constant per unit or it may vary as the quantity purchased increases or decreases.

1.2 Ordering Cost

Ordering cost is incurred whenever the inventory is replenished. It includes cost associated with the processing and chasing of the purchase order, transportation inspection for quality expediting overdue orders and so on. It is also known as the procurement cost.

1.3 Carrying Cost

Also known as the holding cost or the storage cost, carrying cost represents the cost that is associated with storing an item in inventory. Its proportional to the amount of inventory and the time over which it is held. The elements of carrying cost include the opportunity cost of capital invested in the stock; the costs directly associated with storing goods; obsolescence cost; deterioration costs and costs incurred in preventing deterioration and fire and general insurance, etc.

1.4 Stock -out Cost

Stock out cost means the cost associated with not serving the customers. Stock outs imply shortages. If the stock out is internal it would imply that some production is lost resulting in idle time for men and machines, or that the work is delayed which might attract some penalty.

2. Objective

The objectives of this research work is to present the development of construction logistics planning (CLP) model that is capable of integrating and optimizing the critical planning decisions of material procurement and material storage on construction site.

3. Methodology

The methodology adopted in this study is illustrated in Figure 1.

i. Construction logistics planning model is used to minimize the construction logistic cost.

ii. Different optimizing application like time-cost trade off, resource utilization, and site layout planning evolves towards the better solution.

iii. Procurement decisions like fixed order procurement and just in time procurement.

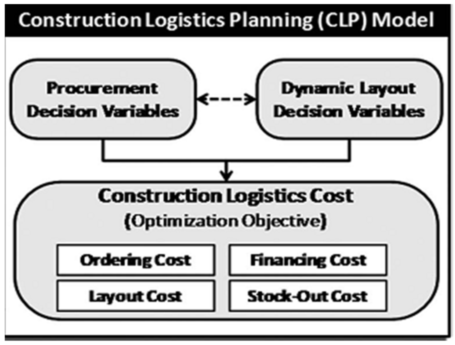


Figure1. Methodology adopted

4. EOQ Model

The classical economic order quantity model also known as the Wilson formulation which the most elementary of all the inventory models. This model is analytical one. For this, first a cost model is developed and then it is manipulated to form an inventory model. The classical EOQ model is shown in Figure 2.and Figure 3.

Q = number of pieces to order.
EOQ = Q^* = optimal number of pieces to order.
D = annual demand in units for the inventory item.
A = ordering cost of each order.
h = holding or carrying cost per unit per year.

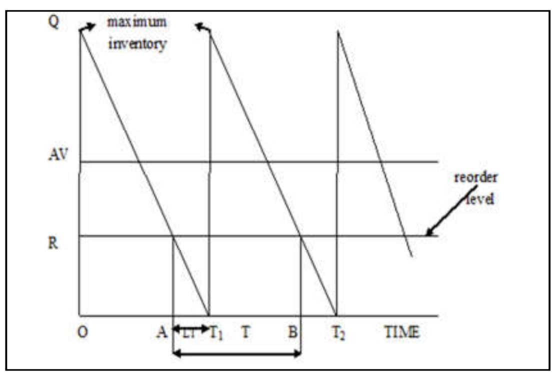


Figure 2 Inventory Model

Total inventory cost = $A * \frac{D}{Q} + h * \frac{Q}{2}$ (1)

EOQ = $Q^* = \sqrt{\frac{2DA}{h}}$ (2)

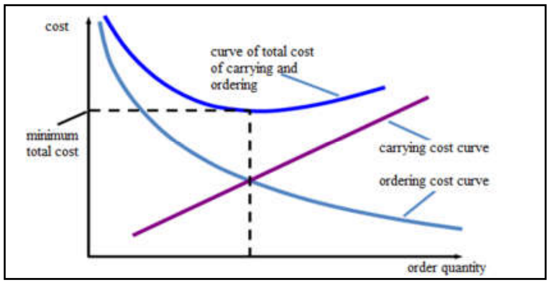


Figure 3 Classical EOQ Model

5. Determination of Reorder Level

i. Once the order quantity is determined, the next decision is when to order.
ii. The time between placing an order and its receipt is called the lead time (L).
iii. Inventory must be available during this period to meet the demand.
iv. When to order is generally expressed as a reorder point – the inventory level at which an order should be placed.
ROP = (demand per day) *(lead time for a new order in days).

The reorder point is shown in Figure 4.

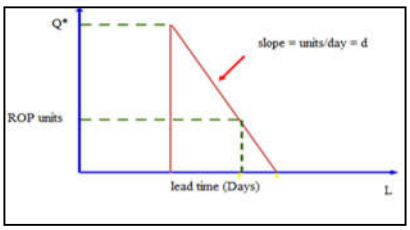


Figure 4 Reorder point

6. EOQ with Price Breaks

As mentioned earlier, the classical EOQ model is based on the assumption that the unit cost of the item under consideration is uniform. In real life, however, it is not uncommon to find price discounts that are based on the quantity for which order is placed. In general, lower rates are quoted if the orders are of a big size. There may be one or more than one price break that may be offered. Clearly, in cases like these, the quantity ordered has to be determined carefully taking into consideration the price levels for the different quantity ranges.

When the unit cost price is uniform, the purchasing cost is irrelevant in determining the order size. But under the condition of price breaks, the item cost, being a function of the order quantity, is the incremental cost and must be included in the cost model. As such the cost model would include the ordering the holding and the purchasing cost of the item.

$$T(Q) = A * \frac{D}{Q} + h * \frac{Q}{2} + C_iD \quad (3)$$

where C_i = price breaks for the different demands of materials.

7. Inventory with Planned Shortages

In general inventory situations, a shortage is considered undesirable and is avoided, if possible. This is because shortage may and are likely to mean loss of customer good will reduction in future orders, unfavorable change in the market share and so on. While in some situations the customer may not withdrawn the orders and wait until the next shipment arrives. This latter situation is called as mentioned earlier the back ordering situation. We shall now develop an inventory model under the assumption that back ordering is possible. The EOQ model assumes that the inventory is replenished precisely when the inventory level falls off to zero as shown in Figure 5. There is no question of shortages and therefore, the cost of shortage is not considered in that model. With assumptions of back ordering, shortages may in fact be deliberately planned to occur. It may be advisable on economic consequent high holding cost. Basically, then, it is a question of setting off the cost of shortages against the saving in the holding cost.

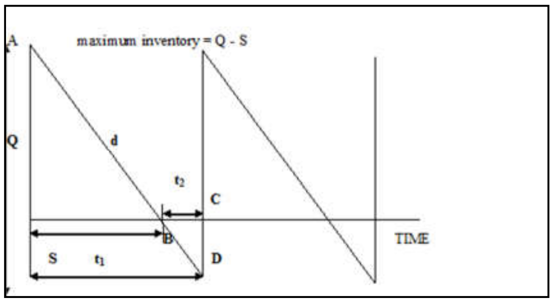


Figure 5 Inventory with planned shortages

Annual Holding cost = $\frac{h*N*T(Q-S)^2}{2Q}$ (4)

Shortage cost = $\frac{b*T*N*S^2}{2Q}$ (5)

8. ABC Analysis

In this analysis, the inventory items in an organization are classified on the basis of their usage in monetary terms. It is very common to observe that usually a small number of items account for a large share of the total cost of material and a comparatively large number of item involve an insignificant share. Based on this criterion, the items are divided into three categories as follows:

A: high consumption value items.
B: moderate consumption value items.
C: low consumption value items.

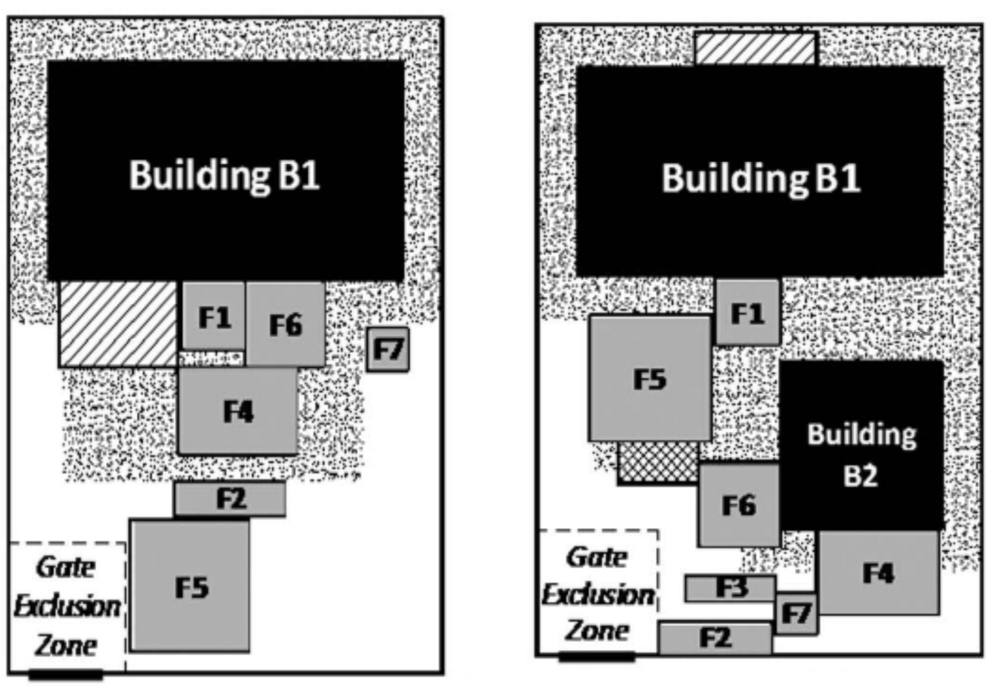
The division of the item into various categories is accomplished by plotting the usage of the item of obtain the ABC distribution curve, which is also called the pareto curve or the curve of mal-distribution. The mechanics of the ABC analysis is given in a step-wise manner.

Step 1: obtain a list of item along with information on their unit cost and the periodic consumption
Step 2: determine the annual usage value for each of the items by multiplying unit cost with number of units and rank them in descending order on the basis of their respective usage value.
Step 3: express the value for each item as a percentage of the aggregate usage value. Now cumulate the percent of annual usage value.
Step 4: obtaining the percentage value for each of the items. For n item shall represent 100/n percent. Thus if there are 20 item involved in classification then each item would represent 100/20=5% of the materials. Cumulate the percentage values as well.
Step 5: using the data on cumulated values of item and the cumulated percentage usage value plot the curve by showing these, respectively on X and Y axis.
Step 6: determine appropriate divisions for the A, B and C categories. The curve world rise steeply up to a point. This point is marked and the item up to that point constitutes the A – type item. Similarly, the curve would only be moderately sloped towards upright. The point beyond which the slope is negligible is marked and the item covered beyond that point is classed as C – type item because they cause only a negligible increase in the cost. The other items are the B- type items for which the curve depicts a gradual upward rise.

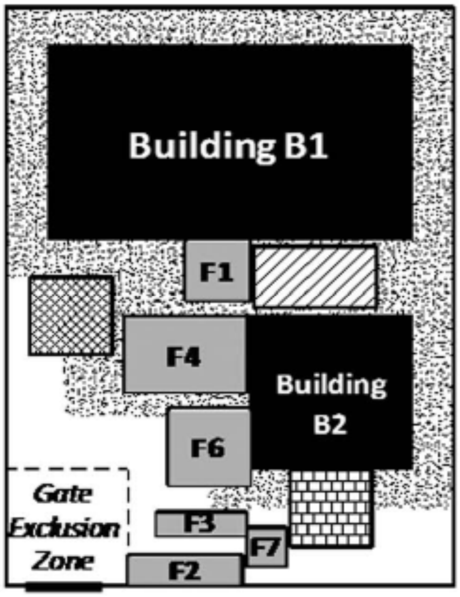
9. Planning of Storage Area

An application example was analyzed to demonstrate the capabilities of the present CLP model in integrating and optimizing procurement and layout decisions while considering their mutual interdependencies. The results of this analysis also illustrate that the material procurement decisions are affected by the criticality of construction activities consuming the material and site space availability, whereas the dynamic site layout decisions are affected by the material procurement decisions and material storage space needs and other site layout constraints.

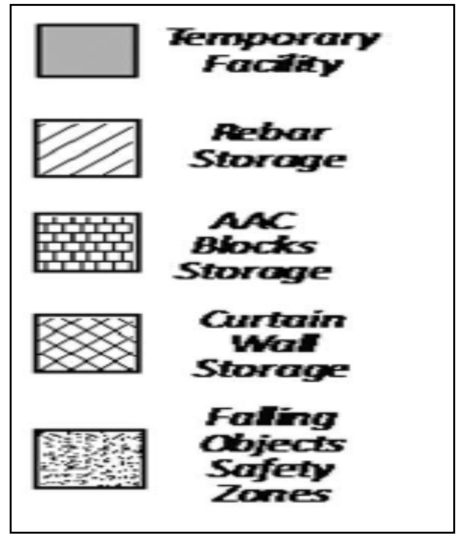
A construction site should be portioned into three areas or zones: semi permanent (exterior) storage, staging areas, and workface (interior) storage. Each has a unique function relative to site material management. The details are shown in Figure 6.



(i) Stage 1 (ii) Stage 2



(iii) Stage 3



(iv) Symbols

Figure 6 Details of Staging area

10.Conclusions

A new model of construction logistics planning was developed to enable the integration and optimization of the critical planning decisions of material procurement and material storage on construction sites. The procurement decision variables in the developed model are designed to identify the fixed-ordering periods of each material in every construction stage to consider the changing demand rates of materials over the project duration. The layout decision variables are designed to identify the locations and orientations of material storage areas and other temporary facilities in each construction stage to consider the dynamic site space needs. The present model utilizes EOQ to generate optimal material procurement and layout decisions to minimize construction logistics costs that include material ordering, financing, stock-out, and layout costs.

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