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Reconciling service levels by customers on a non-constrained production line for raw material and finished goods inventory levels

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"Reconciling service levels by customers on a non-constrained production line for raw material and finished goods inventory levels"

by

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ABSTRACT

Supply chains are often under constant pressure to offer high service level to its customers by efficiently managing inventory levels despite the variability in demand, lead time etc. A national cat litter company, DEF Corporation, is trying to evaluate the optimal levels of inventory, both cycle stock and safety stock on a non-constrained production line which is constrained by the limited storage space for raw material. The research aims to develop an Economic Order Quantity (EOQ) model for DEF Corporation and to determine the amount of finished goods inventory essential to compensate for the limited amount of raw material inventory that could be stocked due to limited storage. The study would also calculate safety stocks to deal with demand uncertainties. The results would provide a model for calculating optimum levels of inventory that would manage demand variability. The study would be beneficial for DEF as it would avoid lost sales due to stock outs.

CHAPTER 1. INTRODUCTION

Managing demand variability has been one of the biggest challenges faced by supply chain managers worldwide. Inability to predict variability in demand can result in either excess of inventory or stock outs (i.e. inadequate inventory) which are both major concerns of demand management (Shea and Gilleon, 2011). In an extremely competitive market today, stock outs may result in loss of business with existing customers either temporary or permanently. Carrying excess inventory is often viewed as a solution to demand variability (Hua and Willems, 2016), further making the issue complex. Several costs are associated with excess inventory due to the requirement of more labor to manage it, more space to hold it, and probably, insurance to protect it in some cases. The excess inventory could also become obsolete further adding on to the cost. Moreover, the capital invested in excess inventory can instead be used efficiently for process improvement like reduction in lead times and eradicating the need to have excess inventory. Forecasting demands and delivering the right number of products at right time in a cost-effective manner is crucial for supply chain managers.

The issue is not just limited to determination of the right amount of inventory with changing consumer demands but to further determine what levels of raw material inventory and finished goods inventory should be maintained individually. Due to the factors like huge fixed costs, storage space, labor or variability in lead times and production systems companies often must decide the balance of both raw materials and finished goods to manage uncertainty in demands. This is a common issue faced by supply chain departments of all firms of varying sizes globally. Although substantive literature is available on inventory management, but each production process is different due to the existence of diverse constraints specific to the system and thus requires case-specific analysis. The research aims to study one such case and develop a model for inventory management, addressing the key limitations specific to the process.

The supply chain department at DEF Corporation, which is a national cat litter company, is struggling with similar issues of efficient inventory management. DEF Corporation needs to determine the right levels of inventory for its unconstrained production line to fulfill the customer demands. The storage space for raw material inventory is limited at DEF, but they own a large warehouse to store adequate amounts of finished goods inventory (Figure 1.1), from where it is transported to its customers after quality check.

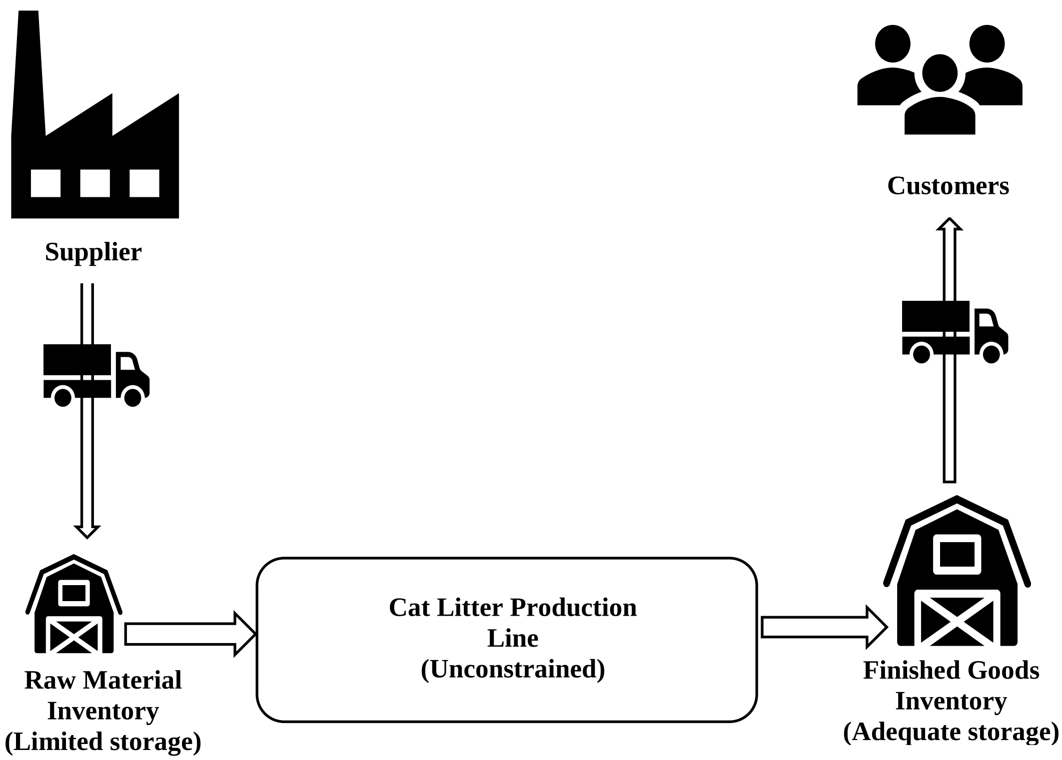

Figure 1.1 *Diagrammatic representation of unconstrained production line at DEF Corporation*

The unconstrained production line at DEF has excess capacity in producing cat litter but its capacity is constrained due to the restricted availability of storage for raw materials at the site. As a result, the production line might have to halt production of certain cat litter formulas when levels of raw material inventories drop and wait until the next batch of raw materials arrive from suppliers, resulting in a temporary stock out of that formula. The supply chain department at DEF Corporation, therefore, must account for such disruptions in the system and accordingly regulate finished goods inventory levels to meet customer needs as they cannot depend on the raw materials inventory in situations of demand variability. The situation is challenging because DEF needs to consider both the constrained storage space for raw materials issue and the uncertainties in the demand of the cat litter while considering the stock levels of finished goods inventory. Thus, the ideal levels of finished goods inventory at DEF should not only meet customer demands successfully but should also be enough to compensate for the lack of raw material inventory which constrains the production line. The optimization of inventory level would benefit DEF Corporation by reducing current losses due to excess inventory or stock outs.

The purpose of this study is to find the optimal levels of finished goods and raw material inventory for DEF Corporation to satisfy customer demand, subject to limited raw material storage. The project aims to analyze the customer service levels by understanding the determining factors like inventory levels, lead time and demand variability. The research questions examined in the proposal are: 1) What would be the optimum level of finished goods and raw material inventory for DEF Corporation under limited raw material storage capacity and 2) What level of safety stocks would be ideal to manage customer demand variations?

ABC/XYZ analysis method would be used to group raw material items into different classes according to their strategic significance, which would help to identify items that need to be prioritized while determining inventory levels to avoid shortage of critical items in production of cat litter. Further, Economic Order Quantity (EOQ) model would be developed to find the optimal quantity of both raw materials and finished goods inventory to be maintained to meet demands at minimum costs addressing the storage constraint issue as well. I would then determine service levels of inventory to calculate safety stock levels to avoid stock outs at DEF Corporation. Finally, an optimization tool would be developed to determine optimum cycle and safety stock levels of raw material and finished goods to meet varying customer demands.

The project would help DEF Corporation to gain competitive advantage in the market by efficiently managing the variability in demands with implementation of optimum finished goods and raw material inventory level. The findings of the study would benefit both direct and indirect users of the system. The supply chain department of DEF Corporation, who would implement and execute the system would be directly profited by saving huge costs. Likewise, indirect users like investors and shareholders would also reap benefits with growth and success of DEF Corporation. Suppliers or consumers who also fall into the category of indirect users would be benefitted with the optimization of inventory levels as it would result in flow of products or raw material in a timely manner without any delays. Furthermore, the scope of the study is not limited to DEF Corporation only, but the findings can be beneficial for all firms that struggle to recognize the optimum levels of inventory with limited storage issues.

CHAPTER 2. LITERATURE REVIEW

Inventory management is essential for reducing operational costs and profit maximization. The model of Economic Order Quantity (EOQ) was first developed by Harris (1913), to determine the optimal order quantity to meet demands with minimum total inventory costs including holding, ordering and backordering (if any) costs. The basic EOQ model assumes demand of a product to be known and constant, which is highly improbable. It further fails to recognize lead times and considers delivery of new orders as soon as the inventory levels are zero. Five years later, Taft (1918) introduced Economic Production Quantity (EPQ) inventory model. Researchers (Hadley and Whitin, 1963; Zipkin, 2000; Goyal and Jaber, 2008; Cárdenas-Barrón, 2010) have since then proposed various optimization methods for inventory management to overcome the limitations of the basic EOQ model proposed. Cárdenas-Barrón (2011), provides a complete review on different optimization methods proposed.

Several modified versions of EOQ model have also been developed for specific product categories like perishable goods (Nahmias, 1982; Padmanabhan and Vrat, 1995; Dye and Ouyang, 2005; Chung and Liao, 2006), imperfect items (Salameh and Jaber, 2000; Cárdenas-Barrón, 2000; Goyal and Cárdenas-Barrón, 2002; Rezaei, 2005; Wee et al., 2007; Rezaei and Salimi, 2012), repairable goods (Mabini et al., 1992; Richter, 1996), reusable items (Koh et al., 2002; Choi et al., 2007) etc. But most of the classical inventory models assume storage capacity to be unlimited whereas in case of DEF Corporation the raw material storage area is limited. Thus, in order to avoid raw material inventory shortages due to limited storage and minimize the total costs at DEF, the study would develop an EOQ model based on the basic model.

For strategic planning of materials and optimization of inventory, classification of items based on their importance is essential (Bruckner and von Wrede, 1998). Depending on the purpose various classification analysis approaches are used to identify and classify items into specific groups. Two of the most commonly used techniques in inventory management are ABC analysis (categorizing items based on consumption) and XYZ analysis (categorizing based on demand variability).

The ABC analysis, based on Pareto's law (i.e. only 20% of total items accounts for the 80% of the total consumption value), is commonly used for classification of items into three categories: A (the most valuable), B (average valuable) and C (least valuable). The ABC analysis method determines the consumption values over a period (demand over period of time* cost per unit) (Pekarčíková et al., 2014) of each item under consideration to group items into different classes. This analysis allows supply chain managers to avoid stock outs of A-items by prioritizing them over B and C items and scheduling frequent orders of such items and planning it cautiously to maintain optimum levels of the inventory.

The XYZ analysis categorizes items according to their fluctuations in consumption (Reiter et al., 2012). The three groups are (Errasti et al., 2010; Wassermann, 2001): X- constant consumption to some extent, fluctuations are rather rare; Y- stronger variations in consumption, mostly due to trend-moderate or seasonal reasons and Z- completely irregular consumption. The XYZ analysis calculates the coefficient of variation (standard deviation of item consumption/ average consumption).

The ABC analysis is used in combination with XYZ analysis for wider applications as it considers both consumption value and demand variability (Reese and Geisel, 1997; Reiner and Trcka, 2004). The ABC/XYZ analysis gives rise to a matrix: AX, BX, CX, AY, BY, CY, AZ, BZ, CZ, which is crucial in understanding which items to prioritize while considering stock management.

CHAPTER 3. RESEARCH MODEL AND HYPOTHESIS

The research model developed for the study is shown in Figure 2. The main theoretical argument of the framework is that demand (D) directly influences the quantity (Q) of inventory to be managed, while the holding cost (H) and set up cost (S) have moderating effect on the inventory level. Further, since storage space is a constraint for DEF Corporation, it would have moderating effect on quantity of raw material inventory. The arguments stated helped to develop the hypothesis which are further explained in the following section.

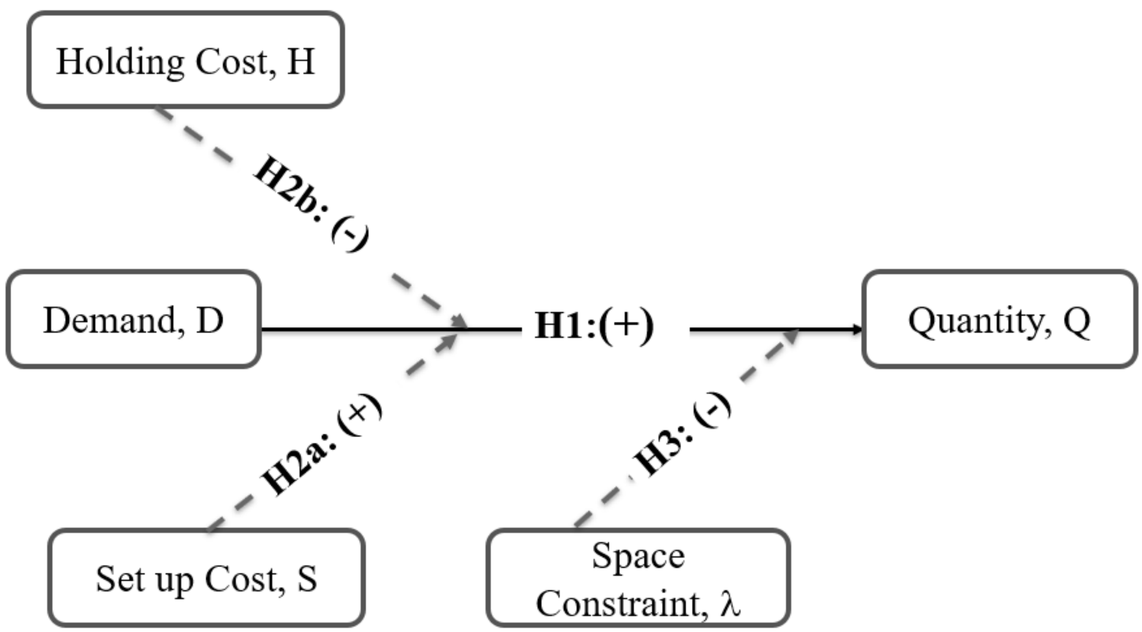

Figure 2. *Research Model*

The research model depicted in Figure 2, is a general model but in reality, *i.e.* specific to the DEF corporation there would be two instances, one for the raw material and another for finished goods inventory. As space constraint factor would only impact raw materials inventory model and not finished goods inventory.

Direct Effect of Demand (D)

Based on the EOQ model developed by Harris (1913) and several other modifications developed by numerous researchers, it is evident that the inventory level is directly influenced by the demand of the product/service. Greater demand of a product signals a company to supply and produce more to meet the demands, which can be achieved by finished goods and raw material inventory levels maintained, thus I hypothesize,

Hypothesis 1 (H1): Greater the demand of cat litter in the market, higher the inventory levels of finished goods and raw material required.

Moderating Effect of Set Up Cost (S)

I propose that the set-up costs have positive influence on the relationship between demand and inventory level. The set-up costs involve the costs required to place order of the raw materials from suppliers. The higher set up costs indicate that placing frequent orders would be expensive for a company, as with each order the high set up costs would be associated. Thus, placing orders with greater raw material quantity to compensate for frequent orders would save both time and money. Thus, in situations when demand is higher requiring high inventory levels, high set up cost would allow placing huge orders of raw material to avoid frequent orders; hence I hypothesize,

Hypothesis 2a (H2a): Set up cost (S) positively moderates the relationship between Demand (D) and the quantity of inventory levels (Q).

Moderating Effect of Holding Cost (H)

I argue that the holding costs have negative influence on the relationship between demand and inventory level. If the holding costs i.e. costs associated with carrying or storing inventory is high, having high levels of inventory would not be cost effective. If the cost of land/warehouse, labor or maintenance is high, then a company would prefer having limited quantity of inventory to meet the demand instead of having surplus. So, although demand for cat litter are high indicating need for high levels of inventory to be stored but high holding costs would be a constraint. Hence, I hypothesize,

Hypothesis 2b (H2b): Holding cost (H) negatively moderates the relationship between Demand (D) and the quantity of inventory levels (Q).

Moderating Effect of Space Constraint (λ):

I posit that if there is limited storage space for raw materials, it would influence the relationship between demand and inventory levels negatively. As observed in the case of DEF Corporation, they have constrained raw material storage and building a new warehouse for storing raw materials would be very expensive. Thus, in current situation, despite the high demand of cat litter, DEF Corporation cannot store high levels of raw material inventory. Hence, I hypothesize,

Hypothesis 3 (H3): Space Constraint (λ) negatively moderates the relationship between Demand (D) and the quantity of inventory levels (Q).

CHAPTER 4. PROPOSED DATA ANALYSIS

Data

The data needed to conduct this analysis would be a secondary data provided by Dr. Bobby Martens and Supply chain Forum. Due to the Non-Disclosure Agreement required by the DEF Corporation, the details are not included. Linear and non-linear optimization methods would be employed in our quantitative study.

ABC/XYZ Analysis

Before planning and controlling optimum levels of inventory, the raw materials required for cat litter production at DEF Corporation need to be classified based on their consumption and demand variability to determine the significance of each item to allow an unconstrained production of cat litter. I would first conduct ABC analysis (Pekarčíková et al., 2014) by first determining annual consumption (annual demand * cost/unit) of each item and then sort the items in descending order of annual consumption. Percentage share of each item on total consumption would then be calculated to determine the items with highest consumption. Then, the items would be classified into A, B and C groups based on their annual consumption with items having highest consumption in group A and least consumption in C.

Since ABC analysis does not consider the demand variability of an item, XYZ analysis would also be done by calculating coefficient of variation of each item, given by

$$Vi = si/hi * 100\ (\%)$$

where,

Vi – coefficient of variation

hi - average consumption of the i-th of material item

si - standard deviation of consumption of the i-th of material item

Then the items are sorted in the ascending order of co-efficient of variation and classified into X, Y and Z group.

The results of ABC/XYZ analysis would then be combined to form a matrix to recognize items that need more attention with respect to others while stocking the inventory of raw materials. The combined ABC/XYZ analysis classification would provide a framework for developing stock management strategy for DEF Corporation.

Economic Order Quantity

To determine the optimum levels of raw material and finished goods inventory EOQ model would be developed. First the finished goods inventory level would be determined based on the demand of cat litter, by the basic EOQ model:

$$\mathbf{Qfi} = \sqrt{\frac{\mathbf{2 * Di * Si}}{\mathbf{Hi}}}$$

where,

Qf = Finished goods quantity

D = Demand

S = Set up Cost

H = Holding Cost

i= 1, ……, n

On evaluating the amount of finished goods level essential to meet demand of the product, I would further calculate the amount of raw materials (Qri) required to produce the demand i.e. calculated amount of finished goods (Qfi). Since the raw material inventory levels are constrained with limited storage space, a storage constraint factor λ is introduced in the EOQ model and calculated as

$$\mathbf{Qri} = \sqrt{\frac{\mathbf{2 * Qfi * Si}}{\mathbf{Hi + 2 * \lambda}}} \qquad \text{Such that, } \sum_{i=1}^{n} \text{Qri} \leq \text{Storage Capacity}$$

where,

Qr = Raw material quantity

Qf = Finished goods quantity

S = Set up Cost

H = Holding Cost

λ = Space constraint factor

i= 1, ……, n

After calculating the inventory level of raw material constrained by storage space, the safety stock levels would be determined to handle demand variations.

Safety Stock

To calculate the safety stock levels, first the optimal service levels i.e. probability of not having stock outs would be determined. The service level is calculated by the following formula:

$$\boldsymbol{p} = \varphi\sqrt{\mathbf{2}\ \boldsymbol{ln}[(\ \mathbf{1}/\sqrt{\mathbf{2}\boldsymbol{\pi}}) * (\boldsymbol{M}/\boldsymbol{H})]}$$

where,

p = Service Level

φ = Cumulative distribution function

M = Marginal unit cost of stock out

H = Holding cost of inventory

The service levels thus depend on only two factors: stock out cost and inventory holding cost. The service levels calculated is then converted into service factor, which is inverse cumulative normal distribution of service level. The safety stock calculation is given by:

$$S\,s = \sigma * icdf(p)$$

where,

Ss = Safety Stock

σ = Standard deviation of error

p = Service Level

icdf = inverse cumulative distribution function

Thus, optimum levels of cycle and safety stocks for efficient inventory management at DEF Corporation would be calculated.

CHAPTER 5. EXPECTED RESULTS

As discussed in the previous sections, this research study aims to determine the optimal levels of both finished goods and raw material inventory for DEF Corporation to meet the customer demand. The research model developed for the study is based on several hypotheses, which would be validated in the results. The expected results for each of the propositions developed are as follows:

Hypothesis 1 (H1)

Greater the demand of cat litter in the market, higher the inventory levels of finished goods and raw material required.

I would fail to reject this hypothesis as demand drives supply of products and increase in demand of cat litter will make it essential for the DEF Corporation to store higher levels of inventory to meet the increasing demand. Earlier researches in the field strongly substantiates this proposition that inventory levels should be aligned to demand of the product to overcome issues like inventory stock outs or excess.

Hypothesis 2a (H2a)

Set up cost (S) positively moderates the relationship between Demand (D) and the quantity of inventory levels (Q).

I would fail to reject this hypothesis as higher set-up costs would make it more feasible for DEF Corporation to store more inventory of raw materials when demands increase. Research suggests that having limited inventory, when set up costs are higher would increase company's expenditure leading to lower profit margins.

Hypothesis 2b (H2b)

Holding cost (H) negatively moderates the relationship between Demand (D) and the quantity of inventory levels (Q).

I would fail to reject this hypothesis. Although the higher demand requires higher levels of inventory to be stored in warehouses of DEF Corporation, but the elevated costs of holding the inventory would constraint the storage of high levels of inventory. Limited inventory level to regulate expenditure on storage would agree with the hypothesis.

Hypothesis 3 (H3)

Space Constraint (λ) negatively moderates the relationship between Demand (D) and the quantity of inventory levels (Q).

I would fail to reject this hypothesis as limited storage area would constraint maintenance of high levels of inventory despite the demand. Research suggest that companies that have limited storage areas to store inventory, overcome the issue by implementation of other approaches like determination of optimal levels of inventory or just-in-time method.

In addition to validation of the research model proposed in the study, the project would help us to regulate both finished goods and raw material inventory depending on the changing customer demand. The study would result in an Excel based decision tool which would calculate optimum levels of raw material and finished goods inventory and would also be capable of being adjusted as per the requirements of DEF Corporation to meet customer demands. Optimization tool would assist in realizing costs associated with different levels of inventory at varying demands. To measure the success of the system proposed in the study, previous dataset from the DEF Corporation would be used as test dataset. The outcomes would be discussed regularly with the stakeholders to monitor the progress.

CHAPTER 6. CONCLUSION

The outcomes of the study will be highly beneficial for DEF Corporation as it would save costs associated with excess inventory or stock outs. The model developed in the project would allow optimal use of resources (time, money and space) and can be implemented by supply chain managers of any company struggling with similar constraints. The model can further be modified and used by companies who have limited storage space for finished goods inventory instead of raw material storage as in case of DEF. Further analysis and remodeling of the proposed model could be used to determine inventory levels for companies who have constrained storage for both raw material and finished good levels.

One of the limitations of the proposed study is that the EOQ model assumes the demand of the product to be constant and instant availability of raw materials to be re-stocked. Thus, the model does not account for any variations in demand due to seasonal or economic effects. Further, the underlying assumption is that the costs of inventory units, ordering charges and holding charges are fixed. To overcome this limitation, continuous monitoring and recalculating inventory and safety stock levels is essential to improve the effectiveness of model.

Another challenge could be having too many definitions for the same data, such as purchase orders and product categories, which could create unnecessary confusion among departments. Standardizing data definitions is crucial in creating an architecture that is common across all departments and avoids any misunderstandings.

In future, DEF could overcome the challenge of space constraints by finding a supplier who can provide just-in-time supply chain. With just-in-time approach there would be no need for DEF to store more to meet customer demands. Optimal safety stock would be sufficient to meet demand fluctuations, and the regular demand could be managed by having raw materials just-in-time.

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