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Simulation of inventory management systems in retail stores: A case study

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ABSTRACT

Inventory management has become a key factor in today's world of uncertainty, particularly in the retail sector. Accordingly, there is a high requirement of managing and controlling the inventory with appropriate policies to elevate the organization's performance. In fact, a proper system has to be implemented for monitoring customer demand. This system will, in turn, assist in maintaining the right level of inventory. In this direction, the present research focuses on a retail store and explores a solution for an inventory-related problem experienced by the firm. A simulation model is developed and run for particular merchandise using Arena simulation software. Rigorous experimentation is conducted with the model by altering the inputs/model characteristics, and a more effective system is proposed. Compared with the existing traditional inventory management system, the proposed system will reduce the inventory level by 40% and lost sales by 87%. Furthermore, the proposed system is optimized using the OptQuest module in Arena simulation software. As a result, the inventory level is further reduced by 73% compared to the existing system. Store managers in various organizations may utilize the proposed methodology for improving their inventory management system.

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1. Introduction

Inventory management has been one of the critical factors in many retail sectors for the past few years [1]. Ensuring both product variety and optimal inventory level is always regarded as an operational challenge for retail outlets [2]. Quite often, a firm's ability to deliver a differentiated strategy is inexplicably linked with its supply chain and inventory management capabilities [3]. Market demand/supplies are dynamic depending upon various factors like seasons, festivals, and past sales data assist companies to anticipate a massive surge of demand in the market well in advance. However, if the firm does not have proper inventory control measures, it will result in a lost case scenario. Furthermore, with frequent lost sales, the retail shop may lose even regular customers. It is reported that nearly 81% of consumers experienced an "out-of-stock" in a period of 1 year. Such lost sales will disappoint customers and undermine the goodwill of the retail outlets. Globally, retailers recorded losses of a whopping $1.75 trillion due to mismanaged inventory [4]. Consequently, effective inventory management policies should be implemented to improve the inventory performance of the firm. From a customer's point of view, it provides better customer services through fast delivery and low shipping charges, hence meeting their expectations.

The main objectives of inventory management include:

1. Ensure a continuous supply of materials, spares and finished goods such that production is not disrupted and the customer's demand is met in a timely manner.
2. Maintain investment in inventories at the optimum level as required by the operational and sales activities.
3. To avoid both overstocking and under-stocking of inventory.
4. To optimize various costs associated with inventories like purchase cost, carrying a cost, storage cost, etc.

Literature review suggests that simulation models are the most appropriate methodology to analyze different inventory management policies [5]. Simulation models enable the investigator to analyse various inventory policies, possible results and their implications [6]. In the present research, demand and inventory

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characteristics of a regular product in a retail outlet is simulated using the popular Arena software.

The remainder of the paper is organised as follows. The notable and relevant papers in the domain are briefly reviewed in the next section. The research methodology is presented in section 3. The detail of the simulation model is described in section 4, followed by the results and interpretation. Finally, the conclusions and directions of future research are articulated in the last section.

2. Literature review

Aggarwal [7] provides an exhaustive review of conventional inventory systems. The paper outlays the variables, parameters, and mathematical formulas related to different inventory control policies that have been already reported in the literature. This article groups various research papers into six categories based on similarities of approaches. A synthesized review of published models belonging to each category is presented, and salient features of individual studies are highlighted. Further, this paper discusses the difficulties that commonly arise in applying these models to routine practical inventory situation; and it also lists the weaknesses (or limitations) of certain assumptions commonly made by the researchers for developing inventory models.

Isotupa & Samanta [8] carried out a comparative study in a lost sale environment and continuous review inventory system, assuming the difference between services to two types of customers using the rationing concept. Demands from each type of customer arrive according to two independent Poisson processes. The paper concludes that the policy of differencing the customer's yields lower cost and lower shortage rates for both types of customers.

Nahmias & Demmy [9] is one of the earliest papers in the (S, Q) inventory system. The paper analyzed a continuous inventory system in the backlogging environment. Assuming fixed lead times, the research classified demand into two classes of high priority and low priority. The paper's objective was to determine the proportion of time each type of demand is met under two different circumstances, i.e., (1) with rationing and (2) without rationing. Moon & Kang [10] also investigated the same scenario and generalized their model to one with compound Poisson demands. Dekker et al., [11] determined the fill rates by analyzing an inventory system with the same demand, lead time and stock out policy followed by Nahmias & Demmy [9] for the lot-for-lot policy. Ha [12] demonstrated that queuing model could be formulated for the lot-for-lot model with two demand classes and backlogging. Sivakumar & Arivarignan [13] analyzed an (s, Q) inventory system with a Markovian arrival process and exponentially distributed lead times for perishable items having an exponentially distributed lifetime. They proposed a system of equations and solved it recursively to determine the inventory level distribution and total cost function. More recently, Gashaw et al., [14] reported a simulation model of a printing enterprise. The paper solved the problem of cost, inventory and resource utilization issues by modeling the existing printing process and inventory management practices of the enterprise.

Prior studies on the (S, Q) system, classifies and priorities customers in a backlogging environment for unmet demand as these systems are mathematically more tractable. However, experimental studies based on simulation models of inventory management systems in a lost sale environment are comparatively less. In this research, we focus on a lost sale environment to minimize the inventory level of a supermarket. The following section explains the methodology of the present research.

3. Research methodology

The fundamental objective of the present study is to find the optimal inventory parameters for a selected product. The details such as customer arrival, demand distribution, purchase patterns corresponding to the selected product are collected from the records. This data is then compared with the analytical model parameters. The firm selected for this case study is the Multipurpose Cooperative Society Supermarket of an educational institution in India. The sales and purchase data corresponding to 12,000 items for the past three years were collected. Data cleaning has been done using MS Excel. It is observed that some items are not regular in demand. Therefore, from the collected data, only regular items are screened for analysis. As a result, 200 items were shortlisted, and the items are arranged by using selective inventory control techniques for prioritization. Details such as lead time, inventory level, and product reorder level are collected from the store owner. The shortlisted 200 items are then prioritized by employing the popular selective inventory control technique known as ABC analysis. Table 1 shows the items prioritized by ABC analysis. Further investigation is carried out on the merchandise that is ranked first in the ABC prioritizing technique. Here, the most valued item 'sugar' is selected for the proposed study and data modeling has been done from the sales and purchases data of the past three years. Based on the demand and purchase characteristics of this chosen item, the present research seeks to obtain the optimal inventory control parameters.

4. Development of simulation model

The simulation model is developed with the popular process-oriented simulation package – Arena. The package provides standard drag-and-drop modules for building the model. The first step in simulation modeling is to synthesize the input data [15]. The selected item is checked for demand patterns from the last two years of sales data using the input analyzer module of Arena simulation software. The distribution is validated from the recent year demand data. Similarly, distributions for the customer arrival and the purchase orders for that particular merchandise are modeled from the customer arrival and purchase data of that merchandise. Table 2 shows the distribution patterns of the item sugar, and the distributions are checked for validation by employing the Kolmogorov-Smirnov (KS) test. KS test is a non-parametric test that compares the cumulative distributions of two datasets based on the following hypothesis:

H_0: There is no statistical difference between the two distributions.

H_1: There is statistical difference between the two distributions.

The table also illustrates the validation of distributions obtained from the input analyzer and checks for the latest year demand patterns. Since p-value > α, we fail to reject the null hypothesis, and it is noted that the distributions are fit for the model. Fig. 1 outlay the simulation model developed in Arena. This model is based on the current inventory system prevailing in the Multipurpose Cooperative Society Supermarket for the selected item, i.e., sugar. The model is built using block and element modules in Arena simulation software in order to impart more practicality to the model. The model with input parameters such as customer arrival, demand and purchase amount distributions are initialized from the distributions data. Here the (S, Q) inventory system has been considered for building this model. The replication length for the model run is set for 365 days. The timing is set between 8 am to 8 pm by using the TNOW function. Furthermore, the warm-up period is set for 60 days to ensure the system has attained a steady state. Safety stock and reorder quantity are then calculated.

Table 1
List of top 10 merchandise prioritized by ABC inventory control technique.

Sl. No	Item	Value (in INR)	Cumulative % AUV (in INR)	Cumulative % of regular items	ABC Class
1	Item 1 (Sugar)	12,49,477	12,49,477.075	6.911973767	A
2	Item 2	11,45,280	23,94,757.075	13.24754044	A
3	Item 3	6,74,910	30,69,667.075	16.9810705	A
4	Item 4	75,384	1,44,92,555.34	80.17126868	B
5	Item 5	72,027.5	1,45,64,582.84	80.56971712	B
6	Item 6	68,251.95	1,47,73,225.35	81.72390524	B
7	Item 7	27,903	1,71,99,908.53	95.14805747	C
8	Item 8	27,084.78	1,72,26,993.31	95.29788759	C
9	Item 9	26,820	1,72,53,813.31	95.44625297	C
10	Item 10	26,343	1,72,80,156.31	95.59197963	C

Table 2
Distribution patterns for the selected merchandise.

Variable	Distribution	Kolmogorov-Smirnov Test (*t*-statistic)	*p*-value (α = 0.05)
Demand Pattern	−0.001 + Expo (51.4)	0.564	0.21
Purchase Pattern	0.999 + 799 * Beta (1.22, 2.34)	0.482	0.18
Customer Inter Arrival	−0.001 + Gamma (0.697, 0.529)	0.349	0.15

The model initially checks for the inventory level with the incoming demand. If the on-hand inventory level is greater than the demand, then the demand will be met, and the inventory level will be updated; if not, it is counted as a lost sale. If demand quantity is greater than the on-hand inventory, then it checks for the reorder level. Suppose the inventory is less than the reorder level. In that case, the order quantity will be replenished by issuing the purchase order along with the delay period, as it accounts for the lead time. This logic is illustrated as a flowchart in Fig. 2.

The demand and customer arrival are random and cannot be altered, but the decision regarding the purchase quantity can be altered by the store in order to reduce the inventory levels. Comparison has been made by considering another scenario considering a fixed purchase quantity, whereas the demand and customer arrival distributions remain the same.

The notations used for this method are as follows:

TC - Total Annual Inventory Cost
D - Annual Demand
Q - Volume per Order
C_o - Ordering Cost per Order
C_c - Carrying Cost per Unit Item
C_u - Unit Cost

$$TC = \left(\frac{D}{Q}\right)C_o + \left(\frac{Q}{2}\right)C_c + D.C_u$$

For constant purchase quantity, economic order quantity is calculated from the total cost equation.

$$EOQ = \sqrt{\frac{2.D.C_o}{C_c}}$$

The ordering cost and the carrying cost were collected from the store records, and the economic order quantity is calculated using the standard formula given below:

Safety stock is calculated from the variable demand and variable lead time data available with the store. It is found from the data that, average demand ($\bar{d}$) = 52 units/day and standard deviation of demand (σ_d) = 50.59 units. Furthermore, Table 3 shows the lead time and its corresponding probabilities.

$$R = \bar{d}L + Z\sqrt{(\sigma_\delta)^2\bar{L} + (\sigma_L)^2\bar{d}^2}$$

Average lead time (L) = 3.1 ≈ 3 days and the standard deviation of lead time (σ_L) = 1.044 days with Z = 1.28 and 90% service level target. The reorder point (R) can be calculated by the formula given below:

Accordingly, Reorder Point (R) = 288 units where Ordering Cost (C_o) is found to be = INR 40 per order, Holding Cost (C_c) = INR 3 per unit and the Unit Cost (C_u) = INR 40. Therefore, the Economic Order Quantity (EOQ) = 667 units.

Variables such as reorder point and inventory level are initialized. The model is run in two scenarios:

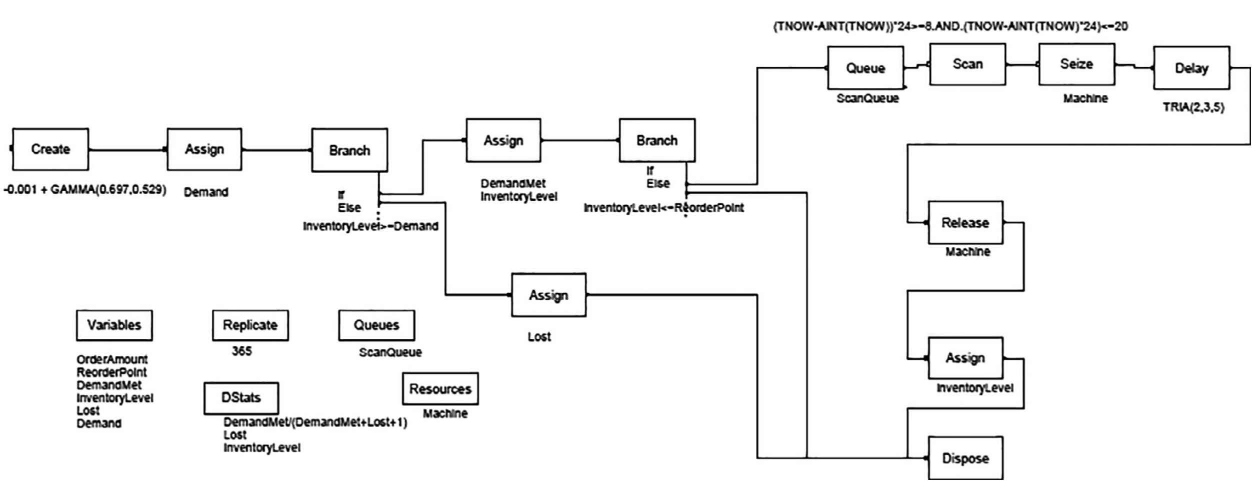

Fig. 1. The Arena simulation model.

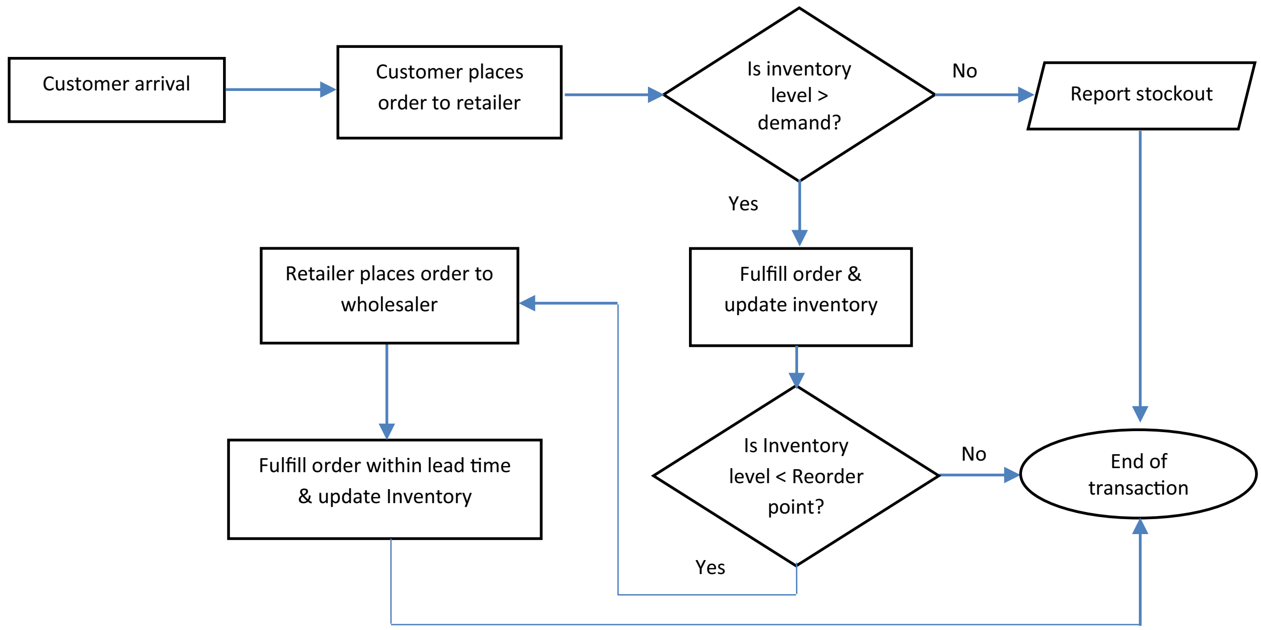

Fig. 2. The simulation logic diagram corresponding to a single transaction.

Table 3
Lead time and its probabilities.

Lead time in days (L)	Probability, P(L)
2	0.3
3	0.5
5	0.2

Scenario 1: Input data distribution for the system is given as observed from the data for customer arrival, demand and purchase quantity.

Scenario 2: Input for the model is given with a fixed purchase quantity as per the economic order quantity while remaining input parameters remains the same.

The proposed system, i.e., scenario 2 is optimized to further reduce the inventory level by adjusting both the order amount and reorder point between the limits. OptQuest optimization module in Arena simulation software is leveraged for optimizing the parameters. Here the objective is to minimize the inventory level while maintaining the service level target as a constraint. The lower bound of service level is assumed to be that obtained from the results of Scenario 2. The control function in OptQuest is deployed to bind the model variables between the limits. As mentioned before, variables such as order amount and reorder points are considered as control parameters for this study.

The developed model is verified and validated prior to inferring the results. Initially, the model is verified to ensure the conceptual model has reflected accurately in the computerized representation. Informal subjective comparisons are conducted for this purpose. The instantaneous count of customers in the system at random time points and total count of customers in the system over a period of time is checked manually and found satisfactory. Subsequently, the model is validated to ascertain that it is an accurate representation of the actual system. Face validity is checked by consulting with the store officials. Furthermore, the customer arrival rate, demand pattern and stockout counts over randomly set time periods are compared against that of the actual system. Though there is slight variation due to the stochastic behaviour of arrival and demand patterns, the results are satisfactory.

4.1. Results and inferences

It is observed from Table 4 that scenario 2 (fixed purchase quantity) has a minimum inventory level compared to the original model, and also, the number of lost customers has considerably reduced. More precisely, the scenario offers a reduction of about 40% reduction in the inventory level and an 87% reduction in lost customers. The service level has increased from 0.63 to 0.94, and the total inventory cost has reduced by 6%.

It can also be noted that the proposed system, when optimized, offers a further reduction in the inventory level by maintaining the service level. More precisely, the optimal plan reduces the inventory level by 73% compared to the traditional system. However, there is a slight increase in the total inventory cost by 4.5% compared to the unoptimized system. It can also be noted that the proposed system, when optimized, offers a further reduction in the inventory level by maintaining the service level. More precisely, the optimal plan reduces the inventory level by 73% compared to the traditional system. However, there is a slight increase in the total inventory cost by 4.5% compared to the unoptimized system. This hike in the total inventory cost is attributed to the increase in the total ordering cost. From Table 5, it is observed that optimal values of the order amount and reorder point are significantly lower when compared to the proposed unoptimized system. Consequently, a larger number of orders will be placed, resulting in a spike in ordering cost that, in turn, increases total inventory cost slightly. From the analysis, it is found that the traditional inventory management system has to be substituted by the proposed system

Table 4
Comparison of the traditional and proposed inventory models.

Parameters	Scenario 1 (Traditional)	Scenario 2 (Proposed)	Scenario 2 (Optimized)
Service Level	0.63630	0.94564	$\geq$ 0.94
Inventory Level	107.15	65.305	29.036
Lost Customers	52.751≈ 53	7.000	7.000
Total Inventory Cost	3.3374E + 05	3.1822E + 05	3.1863E + 05

Table 5
Comparison of the control parameters of the proposed unoptimized and optimized inventory models.

Parameters	Scenario 2 (Proposed)	Scenario 2(Optimized)
Order Amount	667	200
Reorder Point	288	176

that offers considerable cost savings as well as improved customer service.

The proposed inventory management system is implemented in the store for the selected merchandise. The ultimate results obtained from the store are approximately similar to those predicted by the simulation model. The slight deviation is due to the variation in customer's demand and arrival rate. The store is now following the proposed system since it considerably reduces the inventory level.

5. Conclusions

This study proposes a simulation of the inventory system in a supermarket. The simulation model is developed, tested and analyzed using the popular Arena software. The performance measures employed for investigation is the inventory level, and it is directly related to total cost, reorder point and service level. The simulation model was built for the A-category merchandise, considering a continuous review inventory control system. The model is run with both traditional and the proposed ordering policies and the results have been compared. Optimum values for the inventory control parameters are found using the OptQuest module in Arena software, and the results have been compared. It is found that the traditional way of ordering the product is done based on personal intuition and ineffective. Ironically, the store usually maintains a high inventory level and still confronts frequent stock-outs and lost sales. If the store continues to operate in this fashion, it will result in an operational failure resulting from customer dissatisfaction.

Therefore, to improve the existing performance of the store, a new optimal inventory management system is advised. Through simulation, the proposed system is proved to offer considerable improvement in inventory management. Hence, it is suggested to follow the proposed solution for the product while ordering. The store has to incorporate the reorder level and the ordering quantity as proposed with the model in order to obtain better results. To summarize, the contributions of the present research are as follows:

- Developed simulation models of inventory systems in retail stores through a case study.
- Integrated an optimization scheme to the simulation model for effectively managing the inventory of a particular merchandise.
- The presented technique assists the retail firm for informed decision making.

Like any research, the present research also has some limitations. The present study only focused on a single merchandise that was found to be the most crucial as per the ABC analysis. However, to ensure the store's smooth functioning, inventory of all items featuring in category A and category B has to be managed effectively. In this direction, the simulation-based approach proposed in the present research can be easily modified and extended to other items as well.

CRediT authorship contribution statement

Puppala Sridhar: Conceptualization, Methodology, Software. **C. R. Vishnu:** Writing - original draft, Writing - review & editing. **R Sridharan:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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