Journal of Turkish

Operations Management

An inventory optimization model for a textile manufacturing company

Adem PINAR[1*], Durdu Hakan Utku[2], Fatih Kasimoğlu[3]

[1] Department of Logistics Management, University of Turkish Aeronautical Association, 06790, Ankara, Türkiye
* Corresponding author, email: adempinar@yahoo.com, ORCID No: https://orcid.org/0000-0003-0471-7204
[2] Department of Industrial Engineering, University of Turkish Aeronautical Association,06790, Ankara, Türkiye
email: dhutku@thk.edu.tr, ORCID No: https://orcid.org/0000-0002-5755-6101
[3] Department of Industrial Engineering, University of Turkish Aeronautical Association,06790, Ankara, Türkiye
email: ffatihkasimoglu@gmail.com, ORCID No: https://orcid.org/0000-0001-5818-9342

Article Info

Article History:
Received: 20.04.2022
Revised: 23.06.2022
Accepted: 07.07.2022

Keywords

Inventory Management,
Optimization,
Mixed Integer Programming,
ABC Analyses.

Abstract

Inventory management is a crucial issue in most businesses from factories in industry to small and large organizations in the production or service sector. A company should determine an optimum inventory level between excessive inventory that takes up physical space, costs much, and lack of inventory which disrupts the supply chain causing unavailability of the product that makes customers change their idea and buy from another supplier.

In this study, we first classify the items that the company manufactures by using ABC analysis and develop a mathematical model to minimize total cost to enable a better inventory management. We use ABC analysis method to evaluate products in a textile company in terms of importance and to track these products according to their priorities. Accordingly, we propose a mixed integer programming model to determine production quantities and inventory levels with minimum cost. The results shows that the company in concern can improve its total production and inventory costs by 3.8 percent.

1. Introduction

The success of any company which supplies products to its customers depends on companies providing the availability of the demand at the right time, with an appropriate price, and in the requested conditions. All divisions of a firm, especially the design, purchasing, sales, marketing, and production departments should work in a harmony to prepare for these conditions. In many companies, the inventory control function entails dealing with the availability of the products which are especially the main products, spare parts, and consumables. inventory control of a product is precisely balancing the inventory level taking into consideration the trade-off between availability and minimum stock policies. The balancing of these stock levels may even be a challenge among departments of the company. While sales and purchasing departments consider availability a benefit for their aspect, finance, and logistics (warehouse) departments do not like the extra costs and liabilities of high inventory rates (Wild, 2017).

In order to have optimal inventory management, a company is to minimize its inventory while satisfying the customers' demands. In inventory management literature even the optimum inventory level that a firm should maintain has been studied, there is still a dilemma that inventory is both an asset and a liability. Thus, excessive inventory takes up physical space, costs much, and increases the probability of hazard, and loss. Conversely, lack of inventory disrupts the supply chain and causes unavailability of the product which makes customers change their idea and buy from another supplier. Therefore, companies need to use both cost-efficient and competitive inventory management approaches to manage their inventory (Koumanakos, 2008). In this context, some of the problems may arise from the lack of an effective inventory management method; (1) The firms spend too much time calculating order quantities and reorder points to respond to "When to order?" and "How much to order?" questions. (2) Raw materials with high stock levels consume too much space in the warehouse. Conversely, if the raw material stock levels are not sufficient, the production process will not be finalized. (4) Customer demand must be met at a sufficient level.

DOI: 10.56554/jtom.1106406

Considering the abovementioned problems, in this study, we propose an inventory management methodology for a furnishings manufacturing company operating in Ankara. Our proposed approach enables the classification of the critical items with ABC analyses and then optimizes the production quantities and inventory levels with minimum cost. The study shows that production and inventory costs can be considerably reduced with the proposed methodology. In our specific case, the results put forward an improvement of ₺1,369,240 in total cost value, which is tantamount to a 3.8 percent cost decrease.

In Section 2, we reviewed the literature in detail on the research regarding inventory planning and warehouse management. In Section 3 we explain our methodology consisting of ABC-XYZ classification and optimization models. In Section 4, a case study is given and it's solved with the proposed optimization model using GAMS software. In the last section, a conclusion is given with recommendations.

2. Literature Review

In this section, past studies in warehouse management, inventory planning, and buffer stock area optimization are examined as follows:

In early studies, Scarf (1960) conducted a study showing the appropriateness of the use of minimum/maximum (s, S) inventory policy to dynamic inventory problems. Armour and Buffa (1963) found the CRAFT algorithm for settlement problems and CRAFT has become the most popular layout solution algorithm in a short time and changes have been made to the algorithm in line with the requirements. Herron (1976) presented the applications of the ABC curve in Industrial Engineering, Ehrhardt (1979) conducted research on power estimation using the (s, S) inventory policy.

There are many studies on different inventory management policies dealing with order quantity. Silver and Peterson (1985) have presented a mathematical model for a minimum order quantity. If the required quantity is less than the minimum order quantity, the current order may be increased or delayed. In a simple approach, they compared both alternatives in terms of costs to find formulas for safety stock and the threshold of an order.

Janssen et al. (1999) (R, s, Q) discussed the decision to determine the reorder point to meet the customer demand instantly in the inventory model. They argued that the periodic review method would be profitable, as ordering and shipping costs could be reduced when replenishment orders for different products could be properly coordinated. They observed the time interval between requests and demand size data. They considered the problem separately and compared the two models, CR (compound refresh) and DT (discrete-time model), and showed that the DT model can cause major errors and the CR method is a more suitable model.

Some researchers worked on inventory management on environmental protection and healthcare issues. García-Alvarado et al. (2017) focused on the impact of inventory management on environmental protection: They claimed that keeping the inventory at an optimum level is important for environmental health, especially in products that are containing chemicals, and its impact on environmental health should be considered when determining the amount of inventory. Balcik et al. (2016) focused on studies that answer the questions of where, how much, and when to stock in humanitarian supply chains, and these studies are analyzed and reviewed. Pre and post-natural disaster inventory management problem articles are also categorized. The deficiencies in the existing literature are identified and some suggestions are made for future studies. Eissa and Rashed (2020) studied statistical process optimization tools in inventory management and made an application of vendors evaluation in the healthcare sector.

Some researchers studied inventory problems in different logistic areas like maintenance, pipeline, and Ro-ro transportation. Dabiri et al. (2017) focused on the problem of carrying the inventory and inventory transport problem. In their study, transportation and other costs are discussed and a solution method is developed. Poppe et al. (2017) focus on the impact of preventive maintenance on inventory. It is asserted that preventive maintenance equipment increases the demand for spare parts because it does not use its entire life. Chandra et al. (2016) also discuss car transport by sea (ro-ro) by proposing a mixed-integer model for the management of inventory at ports. A time-based heuristic method is also provided. Information numerical results are shown using real data. Moradi and MirHassani (2015) also address the problem of inventory management for petroleum products. In the pipeline connecting a refinery to a distribution center, a mixed-integer model is proposed that optimizes inventory according to daily demand. Computational experiments with real data show that the proposed method gives good results in a short time. Siddiqui et al. (2018) also focus on the problem of carrying inventory in petroleum products. A mathematical model is made to decide whether it should be a pipeline or a sea transport. According to the results of the model, the pipeline stands out in cases where the cost is considered as the only factor, and sea transportation is the more appropriate choice when environmental impacts are considered. A heuristic solution method is also suggested.

Some researchers discussed inventory management regarding the behavioral aspects of the workers and customers. Ancarani et al. (2016) emphasize that employees' overconfidence increases the cost of inventory management. It is

DOI: 10.56554/jtom.1106406

argued that overconfidence generates optimism and, for example, shaping the inventory according to the expectation that sales will be high increases the costs. It is explained that purchasing professionals should be trained to evaluate their success expectations correctly. Li and Fu (2017) also examine the situation where customers turn to other equivalent products in cases where they cannot find their first choice products because they are exhausted. Taking into account this orientation, how can inventory amounts be determined, an optimization model is suggested in this regard. A heuristic method whose closeness to optimum solution has been tested with numerical experiments is also proposed.

There are many other different methods and approaches used in inventory management. Fiestras-Janeiro et al. (2011) view inventory management from the game theory aspect. In this study, game theory applications for a centrally controlled inventory situation are reviewed. Addy-Tayie (2012) dealt with the improvement of a rubber factory's inventory using ABC analyses, reducing the inventory levels, working on shorter lead times, and using a policy of seasonal ordering. Dai et al. (2017) addressed the inventory management problem with its multi-level dimension. Instead of a mathematical modeling approach that only deals with the supplier or the retailer, suggestions have been made on the problem of both minimizing, for example, the total cost of inventory. Rahdar et al. (2018) also proposed a new mathematical model and solution approach for inventory management. The novelty of the approach stems from its dealing with the situation in which the demand and the lead time are both uncertain. Qiu et al. (2019) suggest an inventory model for perishable products. They analyzed delivery amounts in changing manufacturing periods and proposed a branch and cut algorithm. Three valid inequality families are used to reinforce the model presented. The validity of the model is examined through a case study. Alawneh and Zhang (2018) address the problem of inventory management in warehouses. A multi-product mathematical model is proposed that addresses the use of space and uncertainty in demand in warehouses. Solution algorithms are proposed for various uncertain demand situations. Torkul et al. (2016) bring innovation to the safety inventory approach. Using the data of previous periods and evaluating instant conditions, it is possible to predict when the stock will end with statistical analysis, and the approach of managing inventory without keeping a safety inventory is taken into consideration.

3. Methodology

We first apply ABC and XYZ analyses for the determination of inventory priorities. Then we propose a mathematical model to determine optimal production quantities and inventory levels with minimum cost.

3.1 ABC and XYZ Analysis

ABC analysis is used to classify materials regarding their priorities. With this method, the importance of sub-materials used during production is determined and an order policy suitable for each material is followed. The materials are classified into Group A which is very important, Group B that are medium importance, and Group C indicates less or no importance. In the light of these inferences, Group A and B were taken into consideration, whereas Group C materials are ignored as they have little importance. In our case, ABC analysis was applied to our manufacturer based on a cost-based calculation. This cost is the amount of material used for annual products multiplied by its price. With ABC analysis, we focused on important materials and improved inventory management. Besides, the reorder level is revised and the most appropriate order level is determined. Therefore, the optimum ordering quantity according to the inventory level is also calculated to prevent storing too much or too less materials. To summarize, the ABC approach has been applied to our manufacturing company for the following reasons: (1) Focusing attention on important materials and improving inventory management, (2) Improvement in the inspection system, (3) Revising the reorder level, (4) Ordering inventory materials as required and controlling this amount. The products in the inventory are divided into three main groups A, B, and C:

- Group A: It will be used for high-value products. The high level of service received is expensive. The capital invested in buffer inventory is necessary. Strict control and individual control are required.
- Group B: Follows between two extremes. Collective control similar to Group C is made.
- Group C: Used for low-value materials. The high level of service received is cheap. The capital invested in buffer inventory is excessive. It requires more relaxed and collective control.

XYZ analyses can be regarded as an extension of ABC analysis to evaluate the fluctuations in demand for each group of A, B, and C warehouse materials. These materials are classified into X, Y, and Z categories based on the coefficient ratios of 20%: 30%:50% respectively. Category X items are mostly constant and their fluctuation rate is low, namely highly predictable. Category Y items have products from which the fluctuation rate stems especially for seasonal reasons or changes in production trends. Category Z items are irregular in use and show low predictability (Pandya & Thakkar, 2016).

3.2 Mathematical Model

DOI: 10.56554/jtom.1106406

The model to determine optimal production quantities and inventory levels with minimum cost are given as follows.

Sets:

i: Products, $i \in I, I = \{1,2,\dots,n)\}$

t: Periods, $t \in T, T = \{1,2,\dots,m)\}$

Parameters:

$\boldsymbol{Cap_t}$: The capacity in period t

$\boldsymbol{ES_i}$: Safety inventory of item i

$\boldsymbol{y_i}$: yarn cost of item i

$\boldsymbol{p_i}$: painting cost of item i

$\boldsymbol{f_i}$: finishing cost of item i

$\boldsymbol{e_i}$: packaging cost of item i

$\boldsymbol{l_i}$: labor cost of item i

$\boldsymbol{s_i}$: Fixed cost of item i

$\boldsymbol{h_i}$: holding cost of item i

$\boldsymbol{c_i}$: variable cost of item i

$$c_i = y_i + p_i + f_i + e_i + l_i \qquad \forall i \in I$$

$\boldsymbol{IO_i}$ **:** initial quantity of inventory of item i

$\boldsymbol{IS_i}$ **:** final quantity of inventory of item i

$\boldsymbol{D_{it}}$: demand of item i in period t

Decision Variables

$\boldsymbol{X_{it}}$: Production quantity of item i in period t

$\boldsymbol{Z_{it}}$: Binary variable indicating production quantity item i in period t (0 if the quantity is greater than 0, 1 otherwise)

$\boldsymbol{I_{it}^-}$: inventory level of item i in period t immediately before the order arrives

$\boldsymbol{I_{it}^+}$: inventory level of item i in period t immediately after the order arrives

Objective Function

Min (Total Variable Cost + Total Fixed Cost + First Month Holding Cost + Remaining Months' Holding Cost)

$$=\textbf{Min} \ \sum_t \sum_i c_i X_{it} + \sum_t \sum_i s_i Z_{it} + \sum_i h_i \left(\frac{IO_i + I_{i1}^-}{2}\right) + \sum_i \left[\sum_{t=2}^{10} h_i \left(\frac{I_{i(t-1)}^+ + I_{it}^-}{2}\right)\right] \tag{1}$$

S.t.

$$I_{i1}^- = IO_i - D_{i1} \qquad \forall i \in I \tag{2}$$

$$I_{it}^+ = I_{it}^- + X_{it} \qquad \forall i \in I, \ \forall t \in T \tag{3}$$

$$I_{it}^- = I_{i(t-1)}^+ - D_{it} \qquad \forall\, i, 2 \le t \le 10 \tag{4}$$

$$I_{i(10)}^+ \ge IS_i \qquad \forall i \in I \tag{5}$$

$$I_{it}^- \ge ES_i \qquad \forall i \in I, \ \forall t \in T \tag{6}$$

$$X_{it} \le Cap_t Z_{it} \qquad \forall i \in I, \ \forall t \in T \tag{7}$$

DOI: 10.56554/jtom.1106406

$X_{it}, I_{it}^{+}, I_{it}^{-} \geq 0 \qquad \forall i \in I, \ \forall t \in T$ (8)

$z_{it} = \{0, 1\} \qquad \forall i \in I, \ \forall t \in T$ (9)

Our model (1) gives the objective function of minimizing total cost. (2) states the initial inventory constraints for all products. (3) and (4) are the inventory balance constraints. (5) is the ending inventory constraint set. Constraint (6) represents safety inventory levels. (7) defines the capacity constraints. Finally, (8) is our nonnegativity constraint set, and (9) is the binary variable defining constraint.

4. Application and Results

The developed model to determine optimal production quantities and inventory levels with minimum cost are applied to a real textile manufacturing company to test its performance. The company in concern is a medium-sized company that manufactures 18 different textile products. The company has an inventory management problem that causes extra inventory and production costs. The model is used to determine an optimal policy for the inventory management of the company.

To test the model performance we use real data and compare the total cost results with the current value in the absence of the model.

In the company normally there is no inventory classification of the items. Thus, the company applies the same policy without concerning the relative importance of all items. This causes a waste of resources and complicates inventory management. To cope with this problem first ABC/XYZ classification method is used. After the classification of the items, the optimal production quantities and inventory models are determined by using the developed model. Due to the fact that the company has data for a ten-month period in hand, we analyze the company's problem for a period of ten months.

4.1. ABC – XYZ Analysis

The method suggested to be used for the design of the storage area for the inventory in the plant has been prepared by using ABC and XYZ analysis as given in Table 1. In Table 1 the high valued products are classified into category A, while the medium valued and low valued are classified into B and C categories respectively. The respective layout plan is illustrated in Figure 1. The results obtained from the ABC analysis are placed based on the percentages of the products. In the layout figure, the areas shown with gray color are classified into category A, the areas shown with orange color in category B, and the areas shown with yellow color in category C. To make ABC categorization more detailed XYZ analyses are used. For XYZ category classification the reserved areas are marked with the colors in the upper right corner. The regions marked in light blue are in the X category, marked in pink are in the Y category, and the zones marked in light green are in the Z category. The volumes of the products are also taken into consideration in order to use the separated sections with maximum efficiency. Products, except for fabrics that are not packaged in rolls, are stacked using euro pallets. The volume of the zones allocated is directly proportional to the volumes of the products it contains. The packaging desk is the area used for packaging products that are not packaged in their final form. Unpackaged product groups belong to category C and therefore the packing table is positioned near products that are close to category C. The truck lane for transportation is designed as a flat floor at the entrance of the product storage area in order to facilitate the transportation of products. It is designed in width and quality suitable for the use of packaged fabrics and euro pallets.

Table 1. ABC-XYZ classification of the product items

Product	Demand	Price	Revenue (TL)	Revenue/ Demand	ABC-Analysis	XYZ-Analysis
Plain-pattern vintage (PPV) fabric	150,000	120	18,000,000	34.02%	A	AX
Bed linen	50,000	80	4,000,000	7.56%	A	AY
Cotton polyester	50,000	75	3,750,000	7.09%	A	AZ
Drapery	50,000	65	3,250,000	6.14%	B	BX
Colored fabric	100,000	32	3,200,000	6.05%	B	BX
Table cloth Fabric	70,000	45	3,150,000	5.95%	B	BX
Gabardine	50,000	57	2,850,000	5.39%	B	BY
Upholstery fabric	85,000	32	2,720,000	5.14%	B	BY
Drapery fabric	35,000	65	2,275,000	4.30%	B	BZ
Bedspread fabric	22,000	100	2,200,000	4.16%	B	BZ
PVC Table cloth	85,000	25	2,125,000	4.02%	B	BZ

DOI: 10.56554/jtom.1106406

Syntetic tulle	50,000	30	1,500,000	2.84%	C	CX
Quilt	10,000	120	1,200,000	2.27%	C	CX
Quilt cover set	10,000	100	1,000,000	1.89%	C	CY
Satin curtain	50,000	15	750,000	1.42%	C	CY
Blanket	10,000	45	450,000	0.85%	C	CZ
Pillow	15,000	21	315,000	0.60%	C	CZ
Facecloth	10,000	17	170,000	0.32%	C	CZ
Total			52,905,000	100.00%		

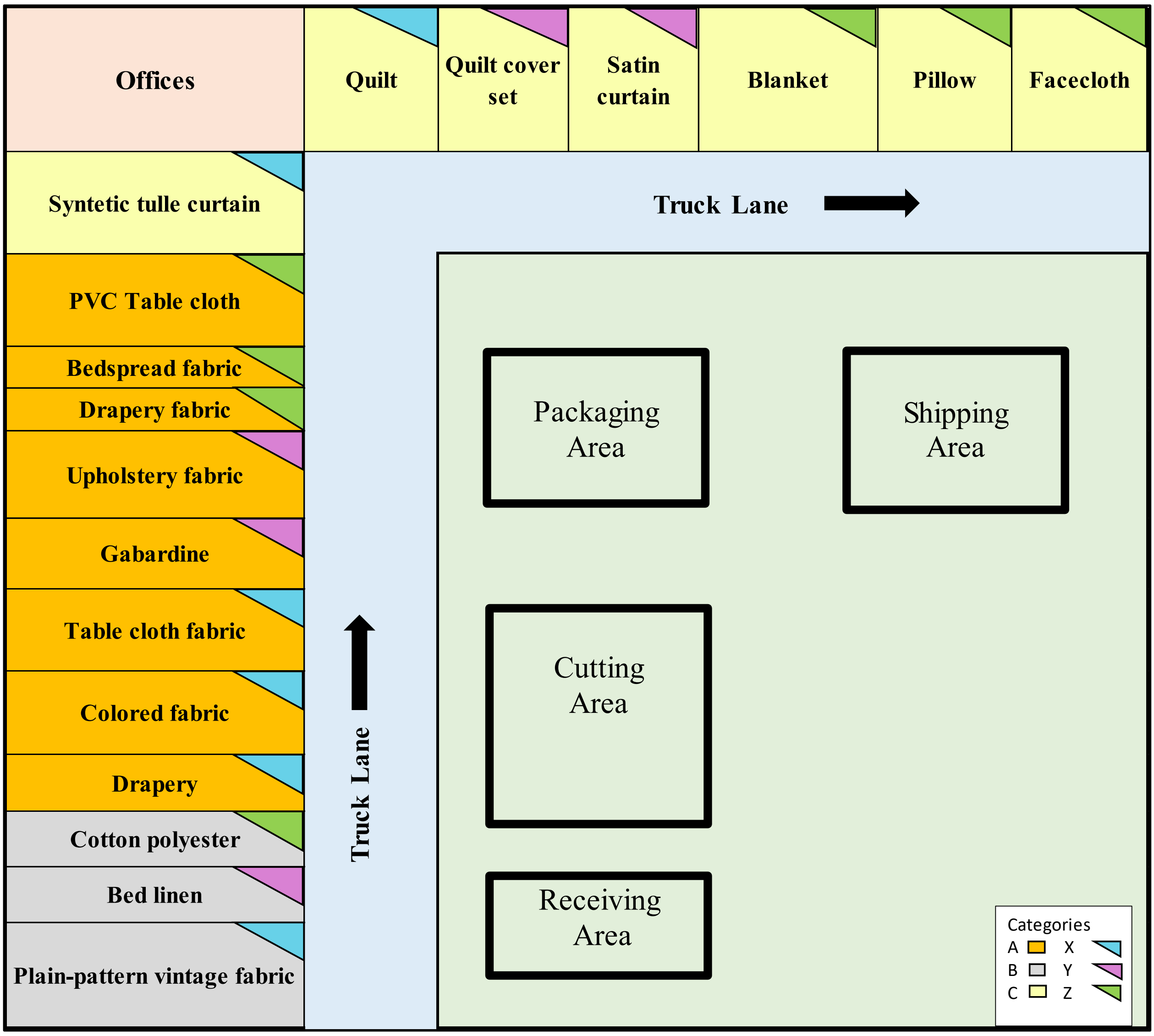

Figure 1. Inventory Layout Plan of the Company

4.2. The Data Used in the Application Problem

The data used in our application is given in Table 2. In Table 2, the data include the names of the products in the rows and associated cost values, prices, demands, safety inventories and the capacities are stated in the columns. Since we could not get the exact values of finishing costs we assume that finishing costs are the same as the painting costs.

Table 2. Cost distribution of the products

DOI: 10.56554/jtom.1106406

Product	Yarn cost (₺)	Painting cost (₺)	Finishing cost (₺)	Packaging cost (₺)	Labor cost (₺)	Fixed cost (₺)	Price (₺)	Demand	Safety inventory	Holding cost (₺)	Capacity
Colored fabric	14.4	3.2	3.2	1	1.28	3.52	32	100,000	2,000	0.64	100,000
Upholstery fabric	14.4	3.2	3.2	1	1.28	3.52	32	85,000	1,000	0.64	100,000
Table cloth Fabric	20.25	4.5	4.5	1.4	1.8	4.95	45	70,000	1,000	0.9	100.000
PPV fabric	54	12	12	3.6	4.8	13.2	120	150,000	3,000	2.4	100,000
Drapery fabric	29.25	6.5	6.5	2	2.6	7.15	65	35,000	500	1.3	100,000
Synthetic tulle	13.5	3	3	0.9	1.2	3.3	30	50,000	500	0.6	100,000
Cotton polyester	33.75	7.5	7.5	2.3	3	8.25	75	50,000	500	1.5	100,000
Drapery	29,25	6,5	6,5	2	2,6	7,15	65	50,000	500	1.3	100,000
Gabardine	25.65	5.7	5.7	1.7	2.28	6.27	57	50,000	500	1.14	100,000
Bedspread fabric	45	10	10	3	4	11	100	22,000	300	2	100,000
PVC Table cloth	11.25	2.5	2.5	0.8	1	2.75	25	85,000	1,000	0.5	100,000
Satin curtain	6.75	1.5	1.5	0.5	0.6	1.65	15	50,000	500	0.3	100,000
Blanket	20.25	4.5	4.5	1.4	1.8	4.95	45	10,000	200	0.9	100,000
Bed linen	36	8	8	2.4	3.2	8.8	80	50,000	400	1.6	100,000
Quilt cover set	45	10	10	3	4	11	100	10,000	400	2	100,000
Quilt	54	12	12	3.6	4.8	13.2	120	10,000	400	2.4	100,000
Facecloth	7.65	1.7	1.7	0.5	0.68	1.87	17	10,000	300	0.34	100,000
Pillow	9.45	2.1	2.1	0.6	0.84	2.31	21	15,000	300	0.42	100,000

4.3. The Optimization Model Results

We use GAMS/CPLEX Version 12 to find a solution for our proposed model (Corporation, 2010). The optimal Z value, which is the total cost, turns out to be ₺34,230,900. Comparing the resulting optimal cost to the current cost in real life in the absence of the model, which is ₺35,600,240. We observe that the cost decreases by 1,369,240 with a 3.8 percent improvement.

Optimal values of production quantities for each product i at each period t ($X_{it}'s$) are given in Table 3. In Table 3, we observe the optimal production quantities of 18 products for the next ten-month period. By using these values the company has the opportunity to hold minimum inventory of the items while satisfying the customers' demands.

Table 3. Optimal values of production quantities for each product i at each period t ($X_{it}'s$)

	Period t									
Product i	1	2	3	4	5	6	7	8	9	10
1	7000	10000	10000	10000	10000	10000	10000	10000	10000	500
2	6000	8500	8500	8500	8500	8500	8500	8500	8500	250
3	3000	7000	7000	7000	7000	7000	7000	7000	7000	250
4	14000	15000	15000	15000	15000	15000	15000	15000	15000	300
5	1600	3500	3500	3500	3500	3500	3500	3500	3500	100
6	2700	5000	5000	5000	5000	5000	5000	5000	5000	100
7	2800	5000	5000	5000	5000	5000	5000	5000	5000	100
8	0	4500	5000	5000	5000	5000	5000	5000	5000	100
9	0	4500	5000	5000	5000	5000	5000	5000	5000	100
10	100	2200	2200	2200	2200	2200	2200	2200	2200	100
11	5000	8500	8500	8500	8500	8500	8500	8500	8500	200
12	3600	5000	5000	5000	5000	5000	5000	5000	5000	100
13	300	1000	1000	1000	1000	1000	1000	1000	1000	100
14	2600	5000	5000	5000	5000	5000	5000	5000	5000	100
15	0	500	1000	1000	1000	1000	1000	1000	1000	100
16	0	0	900	1000	1000	1000	1000	1000	1000	100

DOI: 10.56554/jtom.1106406

17	0	900	1000	1000	1000	1000	1000	1000	1000	100
18	0	0	1300	1500	1500	1500	1500	1500	1500	100

In real life, the companies do not have any choice to determine the exact demands and the orders. The company in concern also has to keep some inventory on hand prior to receiving the actual orders to cope with the uncertainties. Accordingly, we obtain the optimal values of inventory levels of each item i at each period t immediately before the order arrives ($I_{it}^{-}{}'s$) by using the developed model. In this respect, the obtained optimal values of inventory levels for 18 products for a ten-month period are given Table 4.

Table 4. Optimal values of inventory levels of each item i at each period t immediately before the order arrives ($I_{it}^{-}{}'s$)

Product i	**Period t**									
	1	2	3	4	5	6	7	8	9	10
1	5000	2000	2000	2000	2000	2000	2000	2000	2000	2000
2	3500	1000	1000	1000	1000	1000	1000	1000	1000	1000
3	5000	1000	1000	1000	1000	1000	1000	1000	1000	1000
4	4000	3000	3000	3000	3000	3000	3000	3000	3000	3000
5	2400	500	500	500	500	500	500	500	500	500
6	2800	500	500	500	500	500	500	500	500	500
7	2700	500	500	500	500	500	500	500	500	500
8	6000	1000	500	500	500	500	500	500	500	500
9	6000	1000	500	500	500	500	500	500	500	500
10	2400	300	300	300	300	300	300	300	300	300
11	4500	1000	1000	1000	1000	1000	1000	1000	1000	1000
12	1900	500	500	500	500	500	500	500	500	500
13	900	200	200	200	200	200	200	200	200	200
14	2800	400	400	400	400	400	400	400	400	400
15	1900	900	400	400	400	400	400	400	400	400
16	2500	1500	500	400	400	400	400	400	400	400
17	1400	400	300	300	300	300	300	300	300	300
18	3500	2000	500	300	300	300	300	300	300	300

The developed model has also the capability of determining the optimal values of inventory levels of each item i at each period t immediately after the order arrives ($I_{it}^{+}{}'s$). In Table 5, we give the optimal values of inventory levels for 18 products for the time period in concern, which is ten months.

Table 5. Optimal values of inventory levels of each item i at each period t immediately after the order arrives ($I_{it}^{+}{}'s$)

Product i	**Period t**									
	1	2	3	4	5	6	7	8	9	10
1	12000	12000	12000	12000	12000	12000	12000	12000	12000	2500
2	9500	9500	9500	9500	9500	9500	9500	9500	9500	1250
3	8000	8000	8000	8000	8000	8000	8000	8000	8000	1250
4	18000	18000	18000	18000	18000	18000	18000	18000	18000	3300
5	4000	4000	4000	4000	4000	4000	4000	4000	4000	600
6	5500	5500	5500	5500	5500	5500	5500	5500	5500	600
7	5500	5500	5500	5500	5500	5500	5500	5500	5500	600
8	6000	5500	5500	5500	5500	5500	5500	5500	5500	600
9	6000	5500	5500	5500	5500	5500	5500	5500	5500	600

DOI: 10.56554/jtom.1106406

10	2500	2500	2500	2500	2500	2500	2500	2500	2500	400
11	9500	9500	9500	9500	9500	9500	9500	9500	9500	1200
12	5500	5500	5500	5500	5500	5500	5500	5500	5500	600
13	1200	1200	1200	1200	1200	1200	1200	1200	1200	300
14	5400	5400	5400	5400	5400	5400	5400	5400	5400	500
15	1900	1400	1400	1400	1400	1400	1400	1400	1400	500
16	2500	1500	1400	1400	1400	1400	1400	1400	1400	500
17	1400	1300	1300	1300	1300	1300	1300	1300	1300	400
18	3500	2000	1800	1800	1800	1800	1800	1800	1800	400

As a result of determining the categories of the inventory of the items and the optimal values of production quantities and the inventory levels, the company is able to manage the production and inventory of the products at the minimum cost. The results show that there is an improvement of 3.8 percent in total cost.

5. Conclusions and Recommendations

This study is conducted by a furnishings textile manufacturer that is located in Ankara. A model is developed for inventory management of the company using real data. ABC analysis has been used to identify critical inventory items. By using the ABC analysis, 18 items corresponding to 20% of all items that constitute 80% of the customer orders in terms of business have been determined. In order to analyze the existing inventory management policy of the company over the determined items, a model is developed, and a real problem is applied and solved by using the GAMS software. The model can be used for similar companies after making some company-specific changes.

In our application, 10-month consumption values of inventory levels at the end of each month are obtained from the company. The items are classified by using ABC and XYZ analyses; average demand quantity and demand rates are calculated using historical consumption data. Then, a mixed-integer programming model is developed to obtain the optimal inventory levels and production quantities. The results show that the company's total cost decreases from ₺35,600,240 to ₺34,230,900 with a ₺1,369,240 improvement. The percentagewise improvement in production and inventory costs turns out to be 3.8 percent.

For future study, multi-criteria decision-making methods like TOPSIS, VIKOR, and ELECTRE might be applied for the classification of the inventory. Besides, warehouse management systems, robotics technologies, and cloud computing might be used for optimizing the facility layout design. Additionally, to make the model more realistic, the demand uncertainty can be included in the model with a stochastic approach.

Conflicts of Interest

The authors declared that there is no conflict of interest

Contribution of Researchers

Fatih Kasımoğlu and Durdu Hakan Utku carried out model and its calculations, Adem Pınar specify the problem reviewed the literature and contributed to the interpretation of model results. For other parts all authors shared the work.

DOI: 10.56554/jtom.1106406

References

Addy-Tayie, N. (2012). *Improving Warehouse and Inventory Management: Operational Efficiency and Transport Safety*. DOI: https://urn.fi/URN:NBN:fi:amk-2012121018842

Alawneh, F., & Zhang, G. (2018). Dual-channel warehouse and inventory management with stochastic demand. *Transportation Research Part E: Logistics and Transportation Review*, *112*, 84-106. DOI: https://doi.org/10.1016/j.tre.2017.12.012

Ancarani, A., Di Mauro, C., & D'Urso, D. (2016). Measuring overconfidence in inventory management decisions. *Journal of Purchasing and Supply Management*, *22*(3), 171-180. DOI: https://doi.org/10.1016/j.pursup.2016.05.001

Armour, G. C., & Buffa, E. S. (1963). A heuristic algorithm and simulation approach to relative location of facilities. *Management science*, *9*(2), 294-309. DOI: https://doi.org/10.1287/mnsc.9.2.294

Balcik, B., Bozkir, C. D. C., & Kundakcioglu, O. E. (2016). A literature review on inventory management in humanitarian supply chains. *Surveys in Operations Research and Management Science*, *21*(2), 101-116. DOI: https://doi.org/10.1016/j.sorms.2016.10.002

Chandra, S., Christiansen, M., & Fagerholt, K. (2016). Combined fleet deployment and inventory management in roll-on/roll-off shipping. *Transportation Research Part E: Logistics and Transportation Review*, *92*, 43-55. DOI: https://doi.org/10.1016/j.tre.2016.03.014

Corporation, G. D. (2010). *General Algebraic Modeling System (GAMS)*. In (Version 23.5.1)

Dabiri, N., Tarokh, M. J., & Alinaghian, M. (2017). New mathematical model for the bi-objective inventory routing problem with a step cost function: A multi-objective particle swarm optimization solution approach. *Applied Mathematical Modelling*, *49*, 302-318. DOI: https://doi.org/10.1016/j.apm.2017.03.022

Dai, Z., Aqlan, F., & Gao, K. (2017). Optimizing multi-echelon inventory with three types of demand in supply chain. *Transportation Research Part E: Logistics and Transportation Review*, *107*, 141-177. DOI: https://doi.org/10.1016/j.tre.2017.09.008

Ehrhardt, R. (1979). The power approximation for computing (s, S) inventory policies. *Management science*, *25*(8), 777-786. DOI: https://doi.org/10.1287/mnsc.25.8.777

Eissa, M., & Rashed, E. (2020). Application of statistical process optimization tools in inventory management of goods quality: suppliers evaluation in healthcare facility. *Journal of Turkish Operations Management*, *4*(1), 388-408. DOI: https://dergipark.org.tr/en/pub/jtom/issue/56013/706777

Fiestras-Janeiro, M. G., García-Jurado, I., Meca, A., & Mosquera, M. A. (2011). Cooperative game theory and inventory management. *European Journal of Operational Research*, *210*(3), 459-466. DOI: https://doi.org/10.1016/j.ejor.2010.06.025

García-Alvarado, M., Paquet, M., Chaabane, A., & Amodeo, L. (2017). Inventory management under joint product recovery and cap-and-trade constraints. *Journal of cleaner Production*, *167*, 1499-1517. DOI: https://doi.org/10.1016/j.jclepro.2016.10.074

Herron, D. (1976). Industrial engineering applications of ABC curves. *AIIE Transactions*, *8*(2), 210-218. DOI: https://doi.org/10.1080/05695557608975069

Janssen, F., Heuts, R., & de Kok, T. (1999). The impact of data collection on fill rate performance in the (R, s, Q) inventory model. *Journal of the Operational Research Society*, *50*(1), 75-84. DOI: https://doi.org/10.1057/palgrave.jors.2600663

Koumanakos, D. P. (2008). The effect of inventory management on firm performance. *International journal of productivity and performance management*. DOI: https://doi.org/10.1108/17410400810881827

DOI: 10.56554/jtom.1106406

Li, Z., & Fu, Q. G. (2017). Robust inventory management with stock-out substitution. *International Journal of Production Economics*, *193*, 813-826. DOI: https://doi.org/10.1016/j.ijpe.2017.09.011

Moradi, S., & MirHassani, S. (2015). Transportation planning for petroleum products and integrated inventory management. *Applied Mathematical Modelling*, *39*(23-24), 7630-7642. DOI: https://doi.org/10.1016/j.apm.2015.04.023

Pandya, B., & Thakkar, H. (2016). A review on inventory management control techniques: ABC-XYZ analysis. *REST Journal on Emerging trends in Modelling and Manufacturing*, *2*, 15. DOI: http://restpublisher.com/wp-content/uploads/2016/09/A-Review-on-Inventory-Management-Control-Techniques-ABC-XYZ-Analysis.pdf

Poppe, J., Basten, R. J., Boute, R. N., & Lambrecht, M. R. (2017). Numerical study of inventory management under various maintenance policies. *Reliability Engineering & System Safety*, *168*, 262-273. DOI: https://doi.org/10.1016/j.ress.2017.06.012

Qiu, Y., Qiao, J., & Pardalos, P. M. (2019). Optimal production, replenishment, delivery, routing and inventory management policies for products with perishable inventory. *Omega*, *82*, 193-204. DOI: https://doi.org/10.1016/j.omega.2018.01.006

Rahdar, M., Wang, L., & Hu, G. (2018). A tri-level optimization model for inventory control with uncertain demand and lead time. *International Journal of Production Economics*, *195*, 96-105. DOI: https://doi.org/10.1016/j.ijpe.2017.10.011

Scarf, H. (1960). The optimality of (S, s) policies in the dynamic inventory problem. DOI: http://dido.wss.yale.edu/~hes/pub/ss-policies.pdf

Siddiqui, A., Verma, M., & Verter, V. (2018). An integrated framework for inventory management and transportation of refined petroleum products: Pipeline or marine? *Applied Mathematical Modelling*, *55*, 224-247. DOI: https://doi.org/10.1016/j.apm.2017.09.025

Silver, E. A., & Peterson, R. (1985). *Decision systems for inventory management and production planning* (Vol. 18). Wiley.

Torkul, O., Yılmaz, R., Selvi, İ. H., & Cesur, M. R. (2016). A real-time inventory model to manage variance of demand for decreasing inventory holding cost. *Computers & Industrial Engineering*, *102*, 435-439. DOI: https://doi.org/10.1016/j.cie.2016.04.020

Wild, T. (2017). *Best practice in inventory management*. Routledge. DOI: https://doi.org/10.4324/9781315231532

DOI: 10.56554/jtom.1106406