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Research Article

A SAFETY STOCK MODEL BASED ON ORDER CHANGE-TO-DELIVERY RESPONSE TIME: A CASE STUDY FOR AUTOMOTIVE INDUSTRY

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ABSTRACT

The concept of competition has changed from 'competition among companies' to 'competition among supply chains' recently. Therefore, it is necessary to determine safety stock levels through scientific methods by considering customer service level for all companies of a supply chain. In the literature, the mean demand is used to calculate safety stock levels for a specified customer service level. In this study, a rule-based safety stock methodology, considering the order quantity changes immediately before the delivery date of the customer, has been proposed as different from literature. This methodology based on ABC-XYZ analysis provides to classify products according to monetary value and order changes and to propose a safety stock level for each product group in ABC-XYZ analysis. The main motivation is to provide an optimal combination of customer service and stock levels. The proposed methodology has been applied to a company operating in the automotive sector with 1203 products. The safety stock levels were determined according to previous year data and policies on the basis of different behaviors of customers and also the sales.
Keywords: ABC-XYZ analysis, customer service level, response time, safety stock, supply chain management.

1. INTRODUCTION

Supply chain management can be defined as the systematic and strategic coordination of traditional work practices and tactics to improve the long-term performance of companies on both a single chain and the entire supply chain. Operational decisions such as production planning, scheduling, inventory management, and determination of safety stock levels are among the components that have a direct impact on supply chain performance [1]. Communication is a critical concept for success of supply chain management. Communication among supply chain components such as suppliers, manufacturers, distributors, retailers and customers directly effects supply chain performance. At this point, flexible supplier-manufacturer relationship is a key concept in order to cope with changing market conditions. Flexibility enables to respond rapid demand changes [2].

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Production lead-time is a significant concept for inventory management in a manufacturing company. It is necessary to provide shorter lead times not only to meet customer requirements but also to reduce inventory costs [3]. Fu rthermore, a successful inventory management policy depends on two factors as reliability and consistency [1]. In this context, determining inventory levels for each product group is directly related to critical performance indicators of a company such as service level, response time, delivery time, and supply chain effectiveness. In terms of reliability and efficiency of the supply chain, the literature focused on stock level control. Many researchers work in theory and practice in different inventory management subjects such as determining safety stock levels, safety stock placement and minimizing inventory costs [4-6].

In the literature, the rate of responding customer needs at the right time and right amount is defined as customer service level. The company may prefer to keep its inventory levels at the maximum level for product groups in order to increase the customer service level. However, this will result with an increase in inventory costs. Uncertainties regarding stock control in the supply chain structure include customer demand volatility, supplier's deficiency and market conditions. Efficient inventory management keeps inventory level at optimal by preventing both stoppage of production due to stock shortage and high inventory costs due to excess inventory [7]. Safety stock level in the supply chain with uncertain environment requirements is twofold: reducing the amount of stock causes a decrease in the customer service level while increasing the amount of stock will cause to increase in operating and inventory costs. The storage space and volume constraints of the stocks are confronted as another problem.

The main motivation of this study is increasing customer service level as well as decreasing both inventory and operating costs. The purpose of the study is to determine the safety stock levels that maintains the customer service level. While these levels were determining, all the scenarios specific to the product groups of the company were evaluated previously encountered by the company in which the study was conducted. A rule-based safety stock methodology has been developed on the basis of the coefficient of variation, taking into account the variations experienced in customer demands on product basis. The customers with higher coefficient of variation are classified in Z group while the lower variation ones are in X group according to XYZ analysis. In order not to sacrifice from the customer service level, different scenarios are assessed for preventing a backorder in group A products determined by the ABC analysis. The total holding cost of each scenario and the tradeoffs associated with the backorder amounts have been considered within a multi-criteria context. In other words, the novelty of the study is to determine different specific stock policies for the different product groups of the company, according to the coefficient of variation. Another contribution of the study to the literature is the modeling of customer behaviors while determining safety stock levels in the proposed system. The level of consciousness is increased in which the customers behave more decisively and reliably.

The rest of the paper has been organized as follows. A comprehensive literature review has been presented for studies related to safety stock and customer service level in Section 2. The proposed methodology and the case study have been given in Section 3. Finally, the study has been concluded with results and suggestions in Section 4.

2. LITERATURE REVIEW

The most important factors that complicate the supply chain structure are demand fluctuations, keeping customer service level at desired level, stock shortage, capacity increases, inefficiencies in transportation system and production scheduling mistakes. One of the policies that companies prefer to take over from these causes is to keep excess stock. In this case, increasing inventory quantities also increase inventory holding and operating costs [8]. There are many studies that have been proposed to overcome these problems in the literature. Some of these studies are summarized below.

Singh et al. [4] aimed to deter mine lot size and reorder points according to risk adjusted discount rates by using a capital asset pricing approach for inventory management of a company. Desmet et al. [9] aimed to optimise safety stocks in a two-echelon assembly system through several approximation models. Zhou and Viswanathan [10] compared the results of bootstrapping and parametric methods for safety stock determination of spare parts which have intermittent demand. They showed that parametric method has provided better results than bootstrapping method with real industry data. Li et al. [11] examined the effects of lead time and service level constraints on inventory management. They revealed centralized and decentralized models which include these constraints and proposed solution approaches in order to obtain optimum solutions. Jodlbauer and Reitner [12] presented a stochastic production model examining the effect of cycle time, safety stock, processing time, setup time and demand on service level and costs (holding, setup and backorder). Besides, they developed algorithms in order to obtain maximum service level and minimum cost points. Osman and Demirli [5] handled safety stock placement problem including multiple sourced stockpoints which have variable demand and lead time. They aimed to determine fill rate and safety stock level for each stockpoint by using decentralized safety stock placement model and centralized consolidation model in order to increase customer service level and minimize safety stock placement cost. Jeong and Leon [13] studied on coordination of a supply chain with safety stocks under complete and partial information. They obtained optimal solution under complete information and suggested Alternating Direction Method and Diagonal Quadratic Approximation Method for supply chain coordination under partial information. Beutel and Minner [14] presented two approaches which use regression models and linear programming in order to determine safety stock under variable demand. They compared the results of these methods so as to determine inventory levels better. Li and Jiang [15] handled safety stock placement problem as a project scheduling problem and proposed integrated constraint programming – genetic algorithm approach in order to increase solution performance. Chakraborty and Giri [16] developed a model for an unreliable production environment named due to process deterioration, maintanance, machine breakdown and buffer stock. They proposed an algorithm in order to determine safety stock level and production run time for this model. Van Donselaar and Broekmeulen [17] presented an approximation in order to determine safety stocks in a lost sales inventory system under periodic review, positive lead-time and target fill rate. The average and standart deviation of approximation error were calculated for this approximation and the result is considered as very well. Inderfurth and Vogelgesang [18] aimed to determine safety stock levels for a manufacturer in order to handle uncertainties rooted from stochastic demand and different yield randomness. They proposed some approaches for determining static and dynamic safety stocks and examined effectiveness of these approaches via simulation study. Moncayo-Martinez and Zhang [19] formulated supply chain configuration and safety stock placement problem as MAX-MIN ant system which aims to minimize total supply chain cost and lead time concurrently. They presented a bi-objective model and Ant Colony Optimization-based more effective approach. Braglia et al. [20] proposed an analytical approach to the single vendor–single buyer problem under Vendor Managed Inventory with consignment agreement. Tempelmeier and Bantel [21] introduced a methodology in order to investigate the relationship between the inventory system performance and a subsequent transportation process. Safety stock inventory in a two-stage serial line supply chain was optimised in the study of Hua and Willems [6]. Paul and Rahman [22] have developed a fuzzy-based model to overcome sudden supply delays, taking into account demand volatility and safety stock. Woerner et al. [23] aimed to reduce total cost of inventory by providing both budget constraints and service level. They have proposed an algorithm that jointly calculates the optimal capacity allocation and base-stock levels. Saad et al. [24] calculated safety stocks over ERP by taking service levels into consideration. Korponai et al. [25] focused on the relations between the stock level and the risk of shortages. Li and Fu [26] formulated a two-stage optimization model. In the second stage, the worst case demand distribution is characterized by being treated as an input to the inventory levels, while in the first stage optimum stock levels are determined by using the results of the second stage. Lu et al. [27] suggested five allocation policies based on schedule, cost, demand, schedule-cost and schedule-demand in order to support inventory management process. They applied a simulation optimization method based on genetic algorithm for solving inventory model and determining optimal inventory levels for related policy. Darom et al. [28] presented a recovery model for a two-stage supply chain so as to minimize supply disruption by taking into consideration safety stock and carbon emission. As a result of the study, they determined that safety stock level is affected from holding cost for a range of short disruption periods. Kumar and Aouam [29] aimed to optimize strategic safety stock placement and tactical lot sizing problems concurrently by minimizing system-wide production and inventory costs. They utilized an extended dynamic programming algorithm to solve this integrated problem. Trapero et al. [30] proposed an optimal combination of empirical techniques in order to increase safety stock estimation performance. They demonstrated the effectiveness of this approach via simulation and real data experiments. Puga et al. [31] suggested a supply chain design model combining facility location, safety stock placement and delivery strategy decisions so as to improve supply chain design. They determined safety stock placement decisions by means of guaranteed-service approach. Trapero et al. [32] analyzed effects of deviations from i.i.d. (independently and identically distributed) assumption and suggested empirical techniques based on kernel density estimation and Generalised AutoRegressive Conditional Heteroscedastic (GARCH) (1,1) models for determining safety stock levels. They showed the importance of normality deviation and the suitability of kernel density estimation for shorter lead times as a result of this study.

The main sources of uncertainty in the supply chain are twofold: the variability in customer demand on the shipping side (outbound side) and the supply period and order amount on the supply side (inbound side). Methods widely used in the literature to determine the safety stocks take into account distribution measures obtained from statistics on variability in customer demand. However, today, particularly in sectors with very intense competition, due to the special importance attributed to the customer, the extreme flactuation on demands of the customer are also responded. Safety stock quantities are calculated for predetermined customer service levels using the mean and standard deviation values of the past order quantities. Especially when demand is met directly from the stock, it is possible to obtain a high level of customer service for such dynamic inventory items with very high inventory costs. Inventory costs naturally decrease when the order does not have to be met directly from the inventory and a certain production period is available. However, in the latter case, when the customer makes a change in the order quantity very close to the due date, the company may not be able to respond due to limited production capacity. In this case, if the safety stock calculation is made considering the production response time, safety stock amount and the cost will be reduced considerably. In this study, unlike other methods in the literature; a model is proposed which takes into account the quantity changes very close to the customer's delivery date on the basis of the demand is not necessarily met directly from stock and a specific production period is available. The proposed model uses the statistical analysis which define the client's past behavior profile. Using the proposed model structure, it would be possible to respond order quantity changes in a very short period of time in the delivery while maintaining high customer service level and minimizing inventory quantity and cost.

3. METHODOLOGY AND CASE STUDY

The main purpose of this study is to be able to determine safety stock levels against positive order quantity changes that may occur in a certain response time (between order to delivery including production time) before due date. Our second aim is to identify products with high coefficient of variation and to make recommendations for the regulation of customers' ordering policies for these products. Thus, the companies will be able to act proactively with the customer's awareness of the general tendency of behavior, as well as lead customers who behave different from specified in the annual contract. The applied methodology to achieve these goals is described in Figure 1.

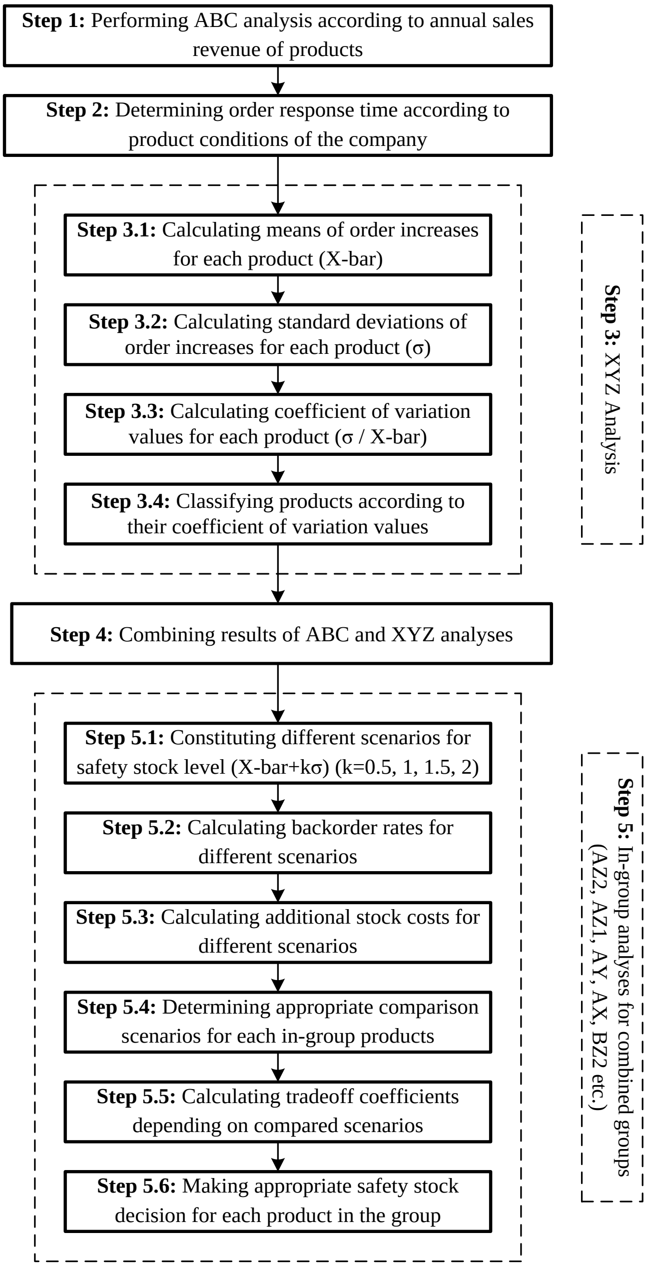

Figure 1. The steps of the proposed methodology

The proposed methodology has been applied for a manufacturing company operating in automotive sector. The company is operating in different locations around the world with 264 customers and 1203 different product types. Arrival time at customer orders varies between 1 month and 18 months and the order quantities can be updated until the delivery time. Since the order updates tend to increase as the delivery time approaches, the company will have difficulty to respond due to the production capacity constraint. The company is able to respond to order variability by two weeks before the delivery. But the company can not take action against later order updates. If customers do not change orders in the last two weeks, the customer service level, which can reach 99%, is on average 80% due to the demanding approach of the customers.

In order to differentiate safety stock policies in product base, variations in customer orders and product values should be taken into consideration. In the literature, ABC analysis for the value-based classification of products and XYZ analysis for the analysis of customer variability are accepted as suitable methods. The company in which the case study is carried out operates in the automotive supplier industry. There are 1203 stock keeping units (SKU) in the product range of company. In order to classify these products according to their annual sales revenue, ABC analysis has been applied. The results of ABC analysis has been presented in Table 1.

Table 1. The results of ABC analysis

Class	SKU	Monetary value (Thousand Euro)	Rate (%)
A	214	97,498	82
B	290	17,325	15
C	699	3,844	3
Total	1203	118,667	100

When a positive change in customer orders occurs, the company can respond to this increase within 2 weeks. Hence, changes made within two weeks prior to the delivery date have been identified as the basic reference point in this study. XYZ analysis has been applied to distinguish this variability based on products. In order to make a more detailed analysis, Z group was evaluated by dividing into two subgroups as Z_1 and Z_2. The classification in the XYZ analysis has been realized according to coefficient of variation values. After checking the normality of the quantity of positive order changes using 0.05 value as the critical significance level, the coefficient of variation has been determined by using the annual means and standard deviations of positive quantity changes for each product. It is determined that the coefficient of variation is within the range of [0.0, 3.0]. The summary results of the XYZ analysis have been presented in Table 2.

The Z_1 and Z_2 product groups, which are defined as having a high coefficient of variation, are products whose order quantities are mostly increased by the customer within two weeks prior to the delivery date. On the other hand, X group products have low coefficient of variation. Due to this distinction, different inventory policies should be applied for inventory items in different groups in XYZ analysis. Since the same assumption is extended to the product groups in the ABC analysis, it is appropriate to use the results of the ABC-XYZ analysis which means the combination of these two analyses in order to make detailed decisions. The summarized data of the combined analysis are given in Table 3.

Table 2. The results of XYZ analysis

Coefficient of variation interval	Number of SKUs	Theoretical rate	Cumulative	XYZ Class	Rate
0.00*	487	0.405	0.405		
0.01-0.49	180	0.149	0.554	X	0.25
0.50-0.99	375	0.312	0.866	Y	0.52
1.00-1.49	120	0.099	0.965	Z1	0.17
1.50-3.00	41	0.035	1	Z2	0.06
Theoretical total	1203	1			
Total	716	0.595			

*There are 487 products that can not be included in analysis, because they have either one or zero positive change in the customer orders during the whole year. For this reason the XYZ classification has been realized for 716 SKUs.

Table 3. The results of the combined ABC-XYZ analysis

	Cost (%)	Product quantity	Coefficient of variation interval
AN*	0.31	3	
AX	3.3	10	0.01-0.49
AY	45.79	124	0.50-0.99
AZ1	23.24	59	1.00-1.49
AZ2	9.53	18	1.50-3.00
BN*	1.29	27	
BX	3.51	70	0.01-0.49
BY	7.8	149	0.50-0.99
BZ1	1.51	34	1.00-1.49
BZ2	0.48	10	1.50-3.00
CN*	1.35	457	
CX	0.76	100	0.01-0.49
CY	0.88	102	0.50-0.99
CZ1	0.19	28	1.00-1.49
CZ2	0.07	12	1.50-3.00
Total	**100**	**1203**	

*Inventory groups named as AN, BN, CN are stock items whose average and standard deviation can not be calculated as previously explained. A specific inventory policy to these products is not proposed and it is recommended to produce when order information is delivered to the order list.

The safety stock has a significant impact on customer service level. Therefore, a number of different scenarios have been examined in order to prevent backorder in group A products. The total holding cost of each scenario and the tradeoffs associated with the backorders have been evaluated within a multi-criteria context. For a clear explanation, the analysis for the group AZ2 which has the greatest coefficient of variation and monetary value is given in Table 4.

Table 4. Analysis table for the products of AZ2 group

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Code	Std Dev. of Positive Differences	Mean of Positive Differences	Coefficient of Variation	Mean + 0.5 std	Mean + 1 std	Mean + 1.5 std	Mean + 2 std	Backorder numbers for different standard deviations				Annual Order Frequency	Backorder rates for different standard deviations				Difference of 1.5Std – 2 std backorder rates	Annual Sales Quantity	Sale Price (Euro)	Additional cost between 1.5 std and 2 std	Annual revenue rate between 1.5 std and 2 std	Trade-off Coefficient	Safety Stock Decision
								0.5 std	1 std	1.5 std	2 std		0.5 std	1 std	1.5 std	2 std							
P1	1403.7	724.8	1.94	1427	2128	2830	3532	57	15	11	7	88	65	17	13	8	4.55	177366	3.05	2146.31	0.0039	1148.69	1.5 Std
P2	725.8	480,0	1.51	843	1206	1569	1932	41	25	18	16	51	80	49	35	31	3.92	106015	8.32	3022.01	0.0034	1145.60	1.5 Std
P3	1054,0	560.7	1.88	1088	1615	2142	2669	81	75	72	64	81	100	93	89	79	9.88	160336	2.87	1514.40	0.0032	3004.95	2 Std
P4	2135.4	1337.8	1.60	2406	3473	4541	5609	61	56	40	28	87	70	64	46	32	13.79	367200	5.82	6222.86	0.0029	4743.60	2 Std
P5	9287.3	5558.3	1.67	10202	14846	19489	24133	7	4	4	4	68	10	6	6	6	0	153620	0.90	4182.42	0.0302	0	1.5 Std
P6	13820,0	9201.5	1.50	16111	23021	29931	36841	26	9	6	4	91	29	10	7	4	2.20	851859	0.47	3310.82	0.0081	270.94	1.5 Std
P7	12486.2	7644.4	1.63	13887	20131	26374	32617	33	11	5	4	73	45	15	7	5	1.37	550060	0.76	4798.52	0.0113	120.69	1.5 Std
P8	1100.9	732.7	1.50	1283	1834	2384	2935	127	70	49	23	184	69	38	27	13	14.13	347490	3.12	1722.06	0.0015	8920.01	2 Std
P9	730.7	332.9	2.19	698	1064	1429	1794	20	18	13	10	109	18	17	12	9	2.75	108390	5.57	2037.41	0.0033	816.58	1.5 Std
P10	779.7	483,0	1.61	873	1263	1653	2042	25	20	18	12	71	35	28	25	17	8.45	46836	7.33	2860.39	0.0083	1015.20	1.5 Std
P11	856.6	489.6	1.75	918	1346	1775	2203	108	58	27	18	406	27	14	7	4	2.22	152600	2.17	929.89	0.0028	789.79	1.5 Std
P12	973,0	446.2	2.18	933	1419	1906	2392	2	1	1	1	57	4	2	2	2	0	17901	38.43	18696.07	0.0271	0	1.5 Std
P13	568.3	244.3	2.33	528	813	1097	1381	1	1	1	1	44	2	2	2	2	0	5411	38.55	10953.21	0.0525	0	1.5 Std
P14	571.7	308.8	1.85	595	880	1166	1452	5	1	1	1	41	12	2	2	2	0	5547	26.09	7458.67	0.0515	0	1.5 Std
P15	272.2	181.3	1.50	317	453	590	726	24	14	14	9	124	19	11	11	7	4.03	40310	16.85	2294.26	0.0033	1194.44	1.5 Std
P16	1127.8	569.8	1.98	1134	1698	2261	2825	1	1	1	1	47	2	2	2	2	0	15390	42.92	24203.81	0.0366	0	1.5 Std
P17	2649.1	1647.9	1.61	2973	4297	5622	6946	168	109	58	35	343	49	32	17	10	6.71	1218895	0.58	780.09	0.0010	6170.55	2 Std
P18	507.6	232.1	2.19	486	740	994	1247	73	63	55	45	389	19	16	14	12	2.57	92481	5.25	1333.77	0.0027	936.67	1.5 Std

The explanations of the variables in columns of Table 4 are given as follows:

In column 1, the company product code,
In column 2, standard deviations of the increased customer order quantities in the two weeks prior to the delivery date,
In column 3, the mean of the increased customer order quantities in the two weeks prior to the delivery date,
In column 4, the coefficient of variation (mean / standard deviation),
In column 5, 6, 7 and 8, the values calculated in the case of having stocks equal to 0.5-1-1.5 and 2 standard deviations respectively, in order to observe the effects of different scenarios,
In column 9, 10, 11 and 12, the number of annual backorders depending on the scenarios given in previous columns,
In column 13, the number of positive order quantity change in the last two weeks before delivery date in customer orders,
In column 14, 15, 16 and 17, backorder rates of different scenarios with stocks equal to 0.5-1-1.5 and 2 standard deviations, respectively,
In column 18, the difference between the backorder rates of 1.5 and 2 standard deviation values (Because AZ2 group includes inventory items with high coefficient of variation and both the annual return of the group is high and the variance of the Z2 group customer order quantities in the last two weeks is high, the standard deviation values are preferred higher. Thus, the customer service level has been increased),
In column 19 and 20, annual sales quantities and unit prices, respectively,
In column 21, annual additional cost if two standard deviation safety stocks are provided instead of 1.5 standard deviations,
In column 22, this value represents the rate of additional cost to the number of stock levels that correspond to 2 standard deviations instead of 1.5 standard deviations in the annual stock,
In column 23, tradeoff coefficient (In the case of a safety stock holding 2 standard deviations instead of 1.5 standard deviations, for instance; for the C00159 stock code product, the rate of 4.55% backorder profit is equal to 1148.7 Euros obtained by proportioning the stock holding additional cost for the values corresponding to the same standard deviations to the value of 0.0040, which is the portion in the profit),
In column 24, decisions regarding final safety stock quantities related to products are included. An overall list of mentioned decisions is given in Table 5 as a set of rules for different stock classes.

Table 5. Rules used to determine safety stock policies for all product groups

Group	1st Rule	2nd Rule	3rd Rule
AZ2	If the annual backorder improvement ratio is equal or over 20% for difference between 1.5-2 standard deviation (std), it is suggested to keep 2 std safety stock quantity by ignoring its cost.	If the annual backorder improvement ratio is equal or less than 5% for difference between 1.5-2 std, it is suggested to keep 1.5 std safety stock quantity by ignoring its cost.	For the difference between 1.5-2 std; if the annual backorder improvement ratio is between 5%-20% and trade off coefficient is less than 2000 it is recommended to keep 1.5 std and if the trade off coefficient is more than 2000 it is recommended to keep 2 std safety stock quantity.
AZ1			
AY			
AX	If the annual backorder improvement ratio is equal or over 20% for difference between 0.5-1 std, it is suggested to keep 1 std safety stock quantity by ignoring its cost.	If the annual backorder improvement ratio is equal or less than 5% for difference between 0.5-1 std, it is suggested to keep 0.5 std safety stock quantity by ignoring its cost.	For the difference between 0.5-1 std; if the annual backorder improvement ratio is between 5%-20% and trade off coefficient is less than 2000 it is recommended to keep 0.5 std and if the trade off coefficient is more than 2000 it is recommended to keep 1 std safety stock quantity.
BZ2	If the annual backorder improvement ratio is equal or over 15% for difference between 1-1.5 std, it is suggested to keep 1.5 std safety stock quantity by ignoring its cost.	If the annual backorder improvement ratio is equal or less than 5% for difference between 1-1.5 std, it is suggested to keep 1 std safety stock quantity by ignoring its cost.	For the difference between 1-1.5 std; if the annual backorder improvement ratio is between 5%-15% and trade off coefficient is less than 1000 it is recommended to keep 1 std and if the trade off coefficient is more than 1000 it is recommended to keep 1.5 std safety stock quantity.
BZ1			
BY			
BX	If the annual backorder improvement ratio is equal or over 15% for difference between 0.5-1 std, it is suggested to keep 1 std safety stock quantity by ignoring its cost.	If the annual backorder improvement ratio is equal or less than 5% for difference between 0.5-1 std, it is suggested to keep 0.5 std safety stock quantity by ignoring its cost.	For the difference between 0.5-1 std; if the annual backorder improvement ratio is between 5%-15% and trade off coefficient is less than 1000 it is recommended to keep 0.5 std and if the trade off coefficient is more than 1000 it is recommended to keep 1 std safety stock quantity.
CZ2	If the annual backorder improvement ratio is equal or over 10% for difference between 0.5-1 std, it is suggested to keep 1 std safety stock quantity by ignoring its cost.	If the annual backorder improvement ratio is equal or less than 5% for difference between 0.5-1 std, it is suggested to keep 0.5 std safety stock quantity by ignoring its cost.	For the difference between 0.5-1 std; if the annual backorder improvement ratio is between 5%-10% and trade off coefficient is less than 1000 it is recommended to keep 0.5 std and if the trade off coefficient is more than 1000 it is recommended to keep 1 std safety stock quantity.
CZ1			
CY	If the annual backorder improvement ratio is equal or over 10% for difference between 0-0.5 std, it is suggested to keep 0.5 std safety stock quantity by ignoring its cost.	If the annual backorder improvement ratio is equal or less than 5% for difference between 0-0.5 std, it is suggested to keep 0.5 std safety stock quantity by ignoring its cost.	For the difference between 0-0.5 std; if the annual backorder improvement ratio is between 5%-10% and trade off coefficient is less than 1000 no safety stock quantity is recommended and if the trade off coefficient is more than 1000 it is recommended to keep 0.5 std safety stock quantity.
CX	It is recommended to produce up to the amount of average order quantity for the products belonging to this group.		

In the ideal situation where customers can plan well and there are not major changes in the market, it is expected that all inventory items will be placed into AX, BX and CX groups except some specific cases such as customer emergencies and natural disasters according to monetary values. However, as seen in Table 3 due to many uncertainties on the part of the customer it appears that the number of materials in the Y and Z groups is highly above the expected values related with exceptional cases. This indicates that order planning systems of the customers are not working conveniently. In order to develop an effective inventory policy, a consensus should be reached within a certain upper limit of the increase in customer order quantities within the last two weeks.

When customers' recent order changes tend to increase, excessive safety stock cost and the risk of backorders occur. On the contrary, if the recent changes tend to decrease, unnecessary holding cost occurs. If the order change process is applied in stricter rules, safety stocks with lower standard deviations can be holded and the company will provide significant cost advantages.

4. CONCLUSIONS AND DISCUSSION

Safety stocks are held to avoid interruption of production and shipment flows that may arise from uncertainty over the supply chain. It is also known that safety stocks are a significant cost item in addition to contribution to reducing uncertainty and increasing customer service levels. Therefore, it is necessary to determine the most appropriate safety stock levels by performing benefit-cost analysis. When the literature is examined, it is generally considered that the supply period and the supply amounts of safety stock levels are calculated on the supply side (inbound logistics); on the shipment side (outbound logistics) it is seen that statistical analysis of the data belonging to the customer orders is considered. As a result of this analysis, safety stock levels are calculated depending on the desired customer service level. When the outbound logistics is considered, safety stocks can respond to changes in customer demands over time with a certain statistical reliability rate. However the safety stock does not take into account recent revisions of the quantity to the order delivery of the customer. For this reason, mean and standard deviation values obtained from the previous order quantities analyzed are higher than the average and standard deviation values of the company's response to the order change, so that the safety stock values calculated according to the literature are higher. In this study, a safety stock determination methodology is proposed based on mean and standard deviations of quantitative changes made during the response period, and customer service level for companies that are able to respond quickly to the revisions of the order quantities, under appropriate production capacity. The proposed methodology integrates ABC analysis and XYZ analysis and enables to classify products corresponding to a automotive company according to their monetary values and order variations. While ABC analysis has been applied to classify products by using monetary values of them, the products have been grouped via XYZ analysis according to their order variations. The products of company have been classified as AZ2, AZ1, …, CY, CX through an ABC-XYZ analysis integrating ABC and XYZ analyses and safety stock decisions have been made for each product group. In the product-based decision making phase, costs of different safety stock levels calculated for various standard deviation levels and backorder rates in this case are analyzed and appropriate safety stock policies are determined. It is possible to say that this is a comprehensive safety stock analysis because of product-based analyses and it can be generalized to other companies which have similar demand characteristic with this company. The suggested safety stock methodology provides to increase customer service level and to decrease inventory costs. As a future study, it can be said that customer behavior analysis can be made based on products. The results can be achieved in the context of customer relationship management so that relationships with customers can be maintained in a particular discipline.

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