Management and Production Engineering Review
Volume 9 • Number 3 • September 2018 • pp. 23–32
DOI: 10.24425/119531

CASE STUDY ABOUT ECONOMIC ORDER QUANTITIES AND COMPARISON OF RESULTS FROM CONVENTIONAL EOQ MODEL AND RESPONSE SURFACE-BASED APPROACH

Ramazan Yıldız[1], Ramazan Yaman[2]

[1] *Çanakkale Onsekiz Mart University, Yenice Vocational School, Çanakkele Turkey*
[2] *Istanbul Gelisim University, Faculty of Engineering and Architecture, Industrial Engineering Department, Avcilar, Istanbul, Turkey*

Corresponding author:
Ramazan Yıldız
Çanakkale Onsekiz Mart University
Yenice Vocational School
Management and Organization Department/Logistics Program
17550 Yenice-Çanakkale/Turkey
phone: +90 286 474 28 68-132
e-mail: ramazanyildizahmet@gmail.com

Received: 4 January 2018
Accepted: 18 July 2018

Abstract
This study involves the implementation of an economic order quantity (EOQ) model which is an inventory control method in a ceramic factory. Two different methods were applied for the calculation of EOQs. The first method is to determine EOQ values using a response surface method-based approach (RSM). The second method uses conventional EOQ calculations. To produce a ceramic product, 281 different and additive materials may be used. First, Pareto (ABC) analysis was performed to determine which of the materials have higher priority. Because of this analysis, the value of 21 items among 281 different materials and additives were compared to the ratio of the total product. The ratio was found to be 70.4% so calculations were made for 21 items. Usage value for every single item for the years 2011, 2012, 2013 and 2014, respectively, were obtained from the company records. Eight different demand forecasting methods were applied to find the amount of the demand in EOQ. As a result of forecasting, the EOQ of the items were calculated by establishing a model. Also, EOQ and RSM calculations for the items were made and both calculation results were compared to each other. Considering the obtained results, it is understood that RSM can be used in EOQ calculations rather than the conventional EOQ model. Also, there are big differences between the EOQ values which were implemented by the company and the values calculated. Because of this work, the RSM-based EOQ approach can be used to decide on the EOQ calculations as a way of improving the system performance.

Keywords
Economic order quantity, Pareto analysis, response surface, demands forecasting.

Introduction

At the beginning of the 19th century, companies had to keep large amounts of inventory to survive. During subsequent times, disadvantages of over-inventory were clearly understood by companies. In the 20th century, the importance of the cost of inventory was understood; therefore, companies implemented basic inventory control methods to manufacture with low quantity inventories [1].

Companies cannot provide on-time production due to over-ordering or under-ordering when they use classical EOQ to procure the materials they need to meet customer needs externally. Calculations with classical EOQ do not yield reliable results for many cases. This situation causes great economic loss for enterprises. It is important to establish the Just-in-Time Production System to ensure that the materials required for production are in stock at the required place. The Kanban system also provides reliable monitoring of material movements in the production environment to ensure on time production. Reliable operation of the specified systems depends on the right operation of the EOQ. We decided to investigate whether there is a more practical and easy way to calculate the EOQ.

There are many disadvantages of high-level inventories including: increasing company capital cost, storage cost (rent, depreciation, maintenance, heating, cooling, etc.), inventory service costs (stacking, loading, unloading, etc.), insurance costs, risk of holding inventory (deterioration, obsolescence, price drop, etc.), and loss of product due to theft and accidents. In addition, large inventories hide real problems and cause unstable backlog and increased waiting times. All the above-mentioned disadvantages cause surges in cost [2–4].

The EOQ model is a very popular and successful model for managing the supply chain. There are many reasons for the popularity of the model such as simplicity in meaning, ease of use and reliability. Many studies were completed about this model and it was developed based on situations in companies [5]. Yu [6] defined uncertainty of data which is about uncertain demand ratio, cost of the order and uncertain holding cost in the EOQ model which he developed. Therefore, he determined two durability criteria and examined them for situations in which distribution of analytic input data is at regular intervals. Grubbström and Erdem [7] developed algebraic derivatives which provide the optimum value to average cost function in their studies. Cardenas-Barron [8] derived economic production quantity (EOQ) as a mathematical model. Minner [9] proved that EOQ has an infinite time horizon and is able to reach a general minimum in his study when he compared cost co-efficient to minimal local costs. In the study which Wee et al. developed in [10], a similar approach was used instead of optimum circuit length to determine optimum party length in the study.

The main goal of this paper is to determine optimum levels of some high-value inventories and to improve inventories in a ceramic factory for better EOQ values. Each improvement could reduce inventory costs at the factory and increase the profitability of the company. Moreover, this study aims to show that the EOQ can be determined by using the RSM (Response Surface Method).

Calculation of the EOQ with the RSM is not in the available literature, in this regard, this is an exemplary study. The classical EOQ calculations for 21 products belonging to groups A and B are defined the first method, whereas the RSM and EOQ calculations are described in the second alternative method. Figure 1 shows the applied approach stages.

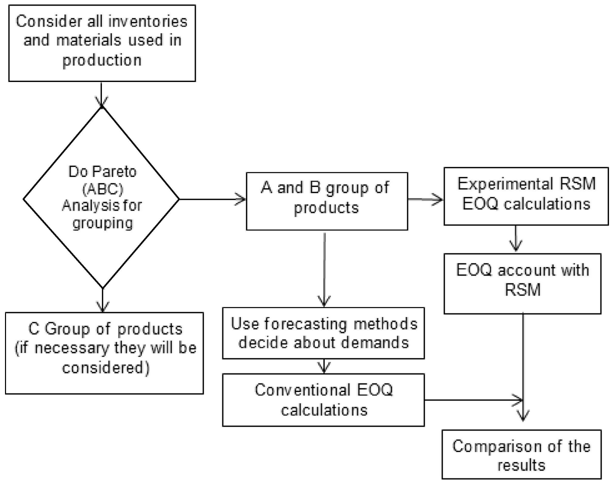

Fig. 1. Work flow chart of the approach.

Optimal Order Quantities models

Economic Order Quantity model

Use of the conventional EOQ model for inventory controls presents satisfactory solutions from different aspects for the companies. This model makes some assumptions which are encountered in real life while presenting solutions [11]. Some of these assumptions are as follows; order quantity is independent of supply time, demand is stable and continuous, purchasing price is fixed, inventory storage cost is a linear function of inventory quantity, ordering costs are fixed for each order and independent from order quantity and lack of inventory is not allowed [12].

This model is shown in Fig. 2, while orders are issued as batches, orders are received at once. At the beginning of each cycle time, per Q units are ordered and delivered instantly. Supply time is zero, and these inventories used to meet the needs and

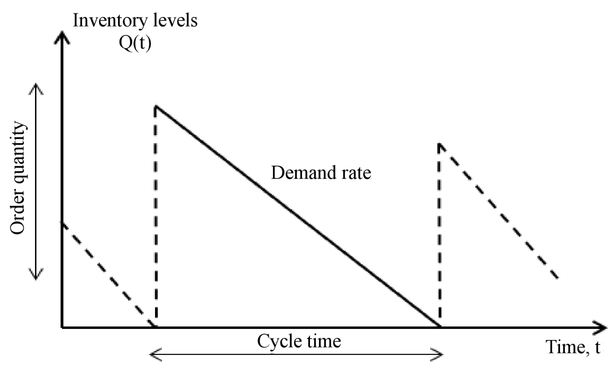

Fig. 2. Economic order quantity model [13].

inventories are decreased by D constant speed, and inventories are re-ordered when they run out [13]

$$\mathrm{EOQ} = \mathrm{Q}^* = \sqrt{\frac{2\mathrm{AD}}{\mathrm{h}}}.$$

The Response Surface Method (RSM) and EOQ

The response surface method was first used by [14]. They developed this method by designated chemical analysis and implementing practical applications in business areas. This work was influential in the development of products and methods in the industry and has to led many kinds of previous research. Many experiments are needed in studies which are conducted with experimental design to find optimal values. Box and Draper [14] found the most appropriate value on a response surface with a few observations and values and conducted combined experiments by gathering some experimental designs together.

The RSM is a combination of mathematical and statistical techniques which are used for development and optimization [15]. This method is a set of statistical techniques which are used to develop an experimental model and evaluate the model. In addition, this method investigates the relationship between a group of dependent variables and a group of controllable variables which affect them with designed, detailed and analyzed experiments.

The RSM ensures the optimization of processes by using mathematical and statistical methods [15]. It investigates analyzed experiment results, a dependent variable and relationships between a group of controllable variables. A model which describes the entire process and experimental design is created by analyzing the interaction of RSM and independent variable values with each other. However, a model which describes the whole process is created with experimental design [16].

The design of the two-level factors can be demonstrated as a form of $2n$. In this case, each of the factors has two levels. The minimum and maximum level of each factor are expressed respectively as -1 and $+1$ [17].

In 2k factorial designs, there are 2 levels for each factor. In this design, an "A" design matrix is created taking all possible combinations of the levels of the k factor into account. In this design, each factor is measured at the lowest level of -1, and at the highest level of the two levels encoded with the $+1$ value.

A matrix of 2^3 design for a model which encoded variables is used and obtained as follows. To find the optimum EOQ; order amount, interest rate and amount of foreign currency are considered

$$A = \begin{bmatrix} -1 & -1 & -1 \\ +1 & -1 & -1 \\ -1 & +1 & -1 \\ +1 & +1 & -1 \\ -1 & -1 & +1 \\ +1 & -1 & +1 \\ -1 & -1 & +1 \\ +1 & +1 & +1 \end{bmatrix} = [a_1 : a_2 : a_3].$$

The RSM allows us to find out how different factors affect the outcome without much experimentation. We decided to use the RSM method because there were variables in the study and a small number of test results were reached. RSM is suitable for solving the problem of EOQ calculations. For optimum EOQ in the RSM method; order quantity, interest rate and currency amount are considered. Firstly, the values used for each product for each year are entered separately in the Minitap program. Then, experimental parameter combinations were calculated from the minimum value (-1) and the maximum value $(+1)$ of the data, and 20 different experimental results were found for each product. The results are calculated according to the variable parameters and the optimum EOQ result was reached.

Analysis and results

The case study for this purpose is a ceramic factory. Two separate EOQ calculations were made for some inventories of the company. The calculation of the first type was carried out by establishing a model. Demand forecast analyses were performed for this calculation. The second type of EOQ calculation was performed with RSM. Firstly, 20 different experiment results were found for EOQ calculations. Then order quantity, interest rate and a variability of the amount of foreign currency were explicated with the response surface method. From this analysis, the minimum EOQ amount was calculated.

In both calculations, ordering costs in the EOQ model were determined as 4.6€ currencies according to the situation of the company. In addition, the data used for holding cost is provided in Table 1.

Many of the materials which are used by the company are imported. Prices of products that were used in the calculation, exchange rate, and relevant date data from the Central Bank of Republic of Turkey (CBT) were considered.

In the ceramic factory, a wide range of products are produced such as floor and wall tiles. This factory uses 281 kinds of auxiliary materials for production.

Table 1
Turkey Central Bank EUR/TRY exchange rate and interest rates.

Interest (TL) and foreign currency (EUR/TRY) rates used in the calculation						
Date	February	April	June	August	October	December
Interest rate 2011	0.0925	0.1010	0.1715	0.1687	0.1596	0.1295
Exchange rate 2011	2.1834	2.1844	2.2928	2.4145	2.4912	2.4703
Interest rate 2012	0.1855	0.1906	0.1856	0.1190	0.1536	0.1050
Exchange rate 2012	2.3210	2.3768	2.3037	2.2094	2.3149	2.3308
Interest rate 2013	0.1496	0.1490	0.1591	0.0990	0.1570	0.1660
Exchange rate 2013	2.3943	2.3235	2.4648	2.5663	2.7300	2.7545
For 2014 Year	January	February				
Interest rate 2014	0.1794	0.2000				
Exchange rate 2014	2.9797	3.0612				

Table 2
Result of the Pareto analysis for the value of 21 ranking items.

Used material name	Abbreviation	Total amount (currencies)
Glucose Zircon Zircobit Mo (5 Micron)	GZZM	836.5
Frits Zirkon Zircobit Fu (325 Mesh)	FZZF	776.3
Zinc Oxide %99.5	CO.99	698.6
Nitre	PN	356.0
Glass Water	CS	240.2
Sodium Tripoly Phoshate (Stpf)/Adisper V-1099	STFA	239.8
Boric Acid	AB	204.8
Grolleg Kaolen/Oka (Akw) 189 Macaroni	GKOM	152.2
Zinc Oxide %95	CO.95	141.7
Red Ttf.354/Ck.270544/Al.23099/Tr.1474/	KTCAT	120.9
Black Ck 33535/Cp NBe 38/Pge 6430/Al 85253	SCCPA	100.9
Aluminum Oxide Seydisehir	AOS	100.8
Euro Ps7	EP	98.1
Black Pg.54011 (Pge.5411)/Al.83045/Tr.13	SPAT	96.6
Aluminum Oxide Mds 6	AOM	94.2
Mt 500 Kil/Rc 399 Kil	MKRK	86.1
Sodium Lignon Sulfonates Bretax-S	SLSB	84.8
Borax Penta/Etibor-48	BPE	84.6
Yellow Ttf.362/Ck.10903kle/Al.53113/Tr.1090	STCAT	84.5
Fp 720 Medium/Semfix Rpt-558	FMSR	79.6
Dxn30004dj Yellow (Kxn03-Exn128)	DY	68.4
Total		4746.5

Pareto (ABC) analysis, which is a simple and convenient method, was completed to determine which of the auxiliary materials used in the factory have higher priorities.

According to the data in Table 2, when products are compared based on their values, the value of 8 different products in group A among 281 product verities is 52%, and there are 13 different products in group "B". Ratio of the products in group A and B to the value of the total product is 70.4%.

EOQ determination with the Response Surface Method

Minimum EOQ for 21 products was calculated by using the RSM. This calculation was performed in the Minitab program. Two levels for each parameter (minimum and maximum) and the three main parameters (variable) which influence the RSM analysis were selected. Variable parameters are demand quantity, interest rate and exchange rate.

20 different experiment results (EOQ) were calculated by taking demand quantity, product price, interest and exchange rates into account for twenty-one products at the relevant date. The RSM was used to achieve optimum results for the economic order quantity. While twenty different calculated EOQ creates the RSM, parameters, demand quantity, interest and exchange rate represent the variable parameters are linked to them.

Minimum EOQ was found as 12.2631 in the calculations belonging to the GZZM product. Based on this value, the ratio of variables was calculated. According to the results, while order quantity is 11.866, interest rate was calculated as 0.2 and exchange rate was found as 3.0612. If variables are different from these values, the amount of EOQ will increase so inventory costs will rise. According to the results, the reliability of the established model is high. R-sq was found as 99.98%, this value means 99.98% of the optimal EOQ results are explained by the independent variable. The mathematical equation to reach these outcomes is;

EOQ = 37.55 – 166.6 Interest rate – 9.25 Exchange rate + 1.155 Order quantity + 359.6 Interest rate*Interest rate + 0.92 Exchange rate*Exchange rate – 0.004016 Order quantity*Order quantity + 12.40 Interest rate*Exchange rate – 2.125 Interest rate*Order quantity – 0.0650 Exchange rate*Order quantity.

In Fig. 3 showing the response surface graph, there are three dimensional interactions among; order quantity, interest and exchange rate values.

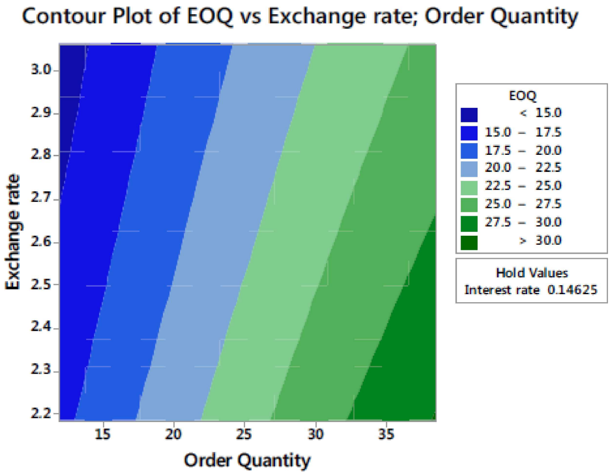

Fig. 3. Contour plot for GZZM product.

According to the results obtained, for this product, the company is supposed to order 40 units instead of 122631 units.

The values of the variables used for the RSM are shown in Table 3.

The calculated min EOQ, order quantity, interest rate, exchange rate and % R-sq which belongs to other products are given in Table 4.

Table 3
Level table for the variables.

	Levels	
Interest rate	the lowest interest rate value	the highest interest rate value
Exchange rate	the lowest exchange rate value	the highest exchange rate value
Order quantity	the lowest order quantity value	the highest order quantity value

Table 4
Calculated values for other products.

Name of the material	Value of the minimum EOQ	Order quantity	Interest rate	Exchange rate	Value of the % R-sq
FZZF	13.994	15.05	0.20	3.06	99.97
CO.99	11.677	10.80	0.20	2.27	99.97
PN	6.458	1.97	0.20	2.27	99.95
CS	86.796	45.82	0.20	1.00	99.97
STFA	12.418	6.35	0.20	2.27	99.98
AB	20.442	10.52	0.20	2.27	99.96
GKOM	34.138	14.63	0.20	3.72	99.95
CO.95	5.404	2.07	0.20	2.27	99.96
KTCAT	0.247	0.07	0.18	3.06	99.94
SCCPA	3.102	0.84	0.20	3.06	99.94
AOS	10.228	2.77	0.20	2.27	100.00
EP	4.422	1.08	0.20	3.06	99.94
SPAT	0.773	0.30	0.20	3.06	99.95
AOM	7.518	2.29	0.20	2.18	99.98
MKRK	48.613	14.40	0.20	3.06	99.95
SLSB	7.557	1.75	0.20	2.27	99.94
BPE	20.284	6.16	0.20	2.27	99.99
STCAT	0.550	0.13	0.20	3.06	99.97
FMSR	3.615	0.69	0.20	3.06	99.93
DY	0.171	0.04	0.16	3.06	99.96

EOQ Calculations using Established Mathematical Model

The amount of demand in the formula must be determined for each period to be able to calculate EOQ accompanied by the model. In determining the demands, time series analysis which is a demand forecasting method was used. While forecasting demand, 8 different methods were used such as trend analysis, quadratic, first single exponential smoothing, second exponential smoothing, double exponential smoothing, harmonic mean, weighted arithmetic mean and linear trend. The method or methods with the coefficient of the lowest error rate were selected for the result of the estimates

Demand forecasting was performed based on 12-month data for the years 2011–2012–2013 and values for the months of January and February of 2014. Actual data for the months of January and February 2014 were compared with forecast data. As a result of benchmarking, the method with lowest error rate was the most appropriate estimation method. The determination process became clearer using estimation results which are shown on the graphic.

Besides this, demand forecasting analyses such as trend analysis, quadratic, single exponential smoothing and double exponential smoothing were performed in the Minitab program. Two different evaluations regarding exponential estimates were made and two different results were found. In the first assessment, the Minitab program made calculations of the initial value of the exponential estimate by averaging the data. In the second calculation related to the exponential estimate, initial value was taken as the first data as in the literature.

The GZZM product demand forecast related to analysis results is provided in Table 5. This includes the results of eight different demand forecasts. In the first exponential estimate calculation, the value of α was taken as 0.14. In the second calculation of the exponential estimate, the value of α was taken as 0.14 again In the double exponential smoothing, alpha value and lambda value were calculated as 0.5. The purpose of the data which were obtained in this way was to obtain a better estimate result.

For this product, the best estimation results according to the graph (Fig. 4) and the error rates in Table 5 are obtained using the first exponential estimation method.

Table 5
GZZM product demand forecasting analysis results.

	January	February	March	April	May	June	July	August	September	October	November	December
2011	37.8	25.3	35.6	32.9	37.0	40.0	38.9	20.8	14.3	15.1	14.4	16.5
2012	20.3	15.1	19.4	14.5	24.7	21.4	25.5	16.9	19.2	20.7	18.4	18.4
2013	18.4	18.3	17.5	18.9	24.8	22.1	25.8	22.4	16.3	7.4	16.0	15.3
2014	25.2	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harmonic mean	23.1	18.7	21.9	19.7	27.8	25.6	28.9	19.8	16.4	12.0	16.1	16.7
Error rate	8.5	−6.6										
Weighted arithmetic mean	20.9	18.1	19.9	19.0	26.0	23.7	27.0	20.6	17.0	12.2	16.6	16.4
Error rate	17.0	−2.8										
First single exponential smoot.	25.2	19.5	23.8	21.9	28.6	27.5	29.8	20.1	16.6	14.3	16.3	16.7
Error rate	0.2	−10.8										
Quadratic analysis	32.4	35.0	29.8	46.1	37.5	42.1	39.8	37.3	5.7	24.9	7.3	7.4
Error rate	−28.3	−99.4										
Exponential growth	11.8	13.9	11.3	12.0	19.0	14.7	19.5	21.5	18.9	6.5	18.1	15.5
Error rate	53.2	21.1										
Double exponential smoothing	2.3	12.7	6.2	8.3	16.8	10.0	17.0	21.8	18.6	6.6	17.9	15.5
Error rate	91.0	27.8										
Linear trend analysis	6.2	12.6	6.1	8.2	16.7	9.9	16.9	21.7	18.7	6.7	17.9	15.5
Error rate	75.6	28.4										
Second exponential smoothing	32.96	23.12	31.10	28.72	33.80	35.25	35.45	20.55	15.14	14.7	15.1	16.6
Error rate	−30.7	−31.6										

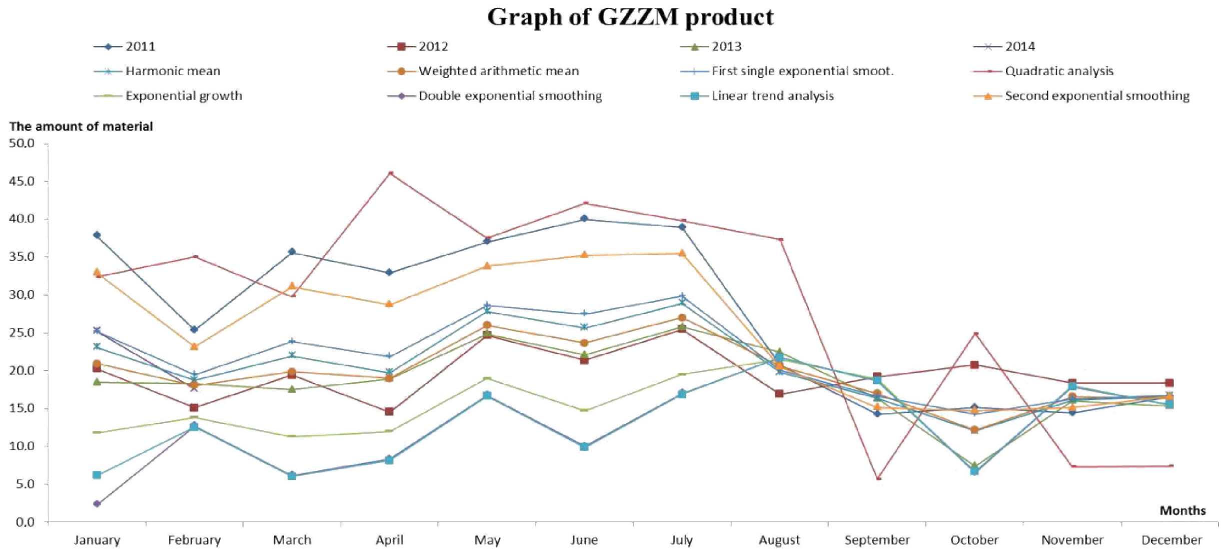

Fig. 4. Graphical representation of the demand forecast results.

Table 6
Comparison of the data calculated with the company data.

Stock name	Implemented by the company (EOQ1)	Analyzed by the RSM (EOQ2)	Analyzed by mathematical model (EOQ3)	Difference (EOQ2-EOQ3)	Difference (EOQ1-EOQ2)	Cost (Currency)	Ordering period of the company (Day)	Ordering period of the calculations (Day)
MKRK	80.0	48.61	64.05	−15.44	31.39	15.2	30	55
CS	120.0	86.80	101.95	−15.15	33.20	12.9	30	39
GKOM	40.0	34.14	42.05	−7.91	5.86	5.5	30	43
AOM	8.4	7.52	10.17	−2.65	0.88	3.2	30	46
CO.99	10.8	11.68	14.41	−2.73	−0.88	7.4	30	19
STFA	44.8	12.42	15.09	−2.67	32.38	83.6	30	34
GZZM	40.0	12.26	16.15	−3.89	27.74	115.9	30	17
FZZF	43.2	13.99	15.63	−1.64	29.21	120.2	30	21
AB	10.4	20.44	23.95	−3.51	−10.04	16.9	30	38
BPE	10.4	20.28	24.16	−3.88	−9.88	12.6	30	63
SCCPA	8.0	3.10	4.61	−1.51	4.90	32	30	52
PN	9.6	6.46	7.68	−1.22	3.14	12.4	30	67
SLSB	10.0	7.56	10.62	−3.06	2.44	7	30	62
AOS	10.0	10.23	14.62	−4.39	−0.23	0.8	30	54
CO.95	10.0	5.40	6.95	−1.55	4.60	22.5	30	44
EP	8.0	4.42	6.53	−2.11	3.58	16.6	30	53
FMSR	8.0	3.62	7.21	−3.59	4.38	18.3	30	40
SPAT	1.2	0.77	0.91	−0.14	0.43	15.4	30	54
STCAT	1.2	0.55	0.81	−0.26	0.65	24.4	30	54
KTCAT	0.8	0.25	0.41	−0.16	0.55	45.2	30	34
DNY	0.2	0.17	0.28	−0.11	0.03	3.4	30	50

The GZZM product was selected from among the 21 items. This product has the highest value in the Pareto analysis. The analysis results of the other products are given in Table 6.

According to the data in Table 6, EOQ of MKRK, CS, GKOM, AOM, STFA, GZZM, FZZF, SCCPA, PN, SLSB, CO.95, EP, FMSR, SPAT, STCAT, KTCAT and DNY products are more than what the company determined. Also, EOQ was lower than what the company determined for CO.99, AB, BPE, AOS and DNY products.

Times to order each product were determined as 30 days by the company in order to better manage the different order periods of each part. As can be seen from the analysis, demands are highly variable. In this instance, the time for optimal order is different for each product. The most appropriate ordering time which we proposed to the company is included in the table

Conclusions and recommendations

Companies in today's conditions must tightly control their total cost in addition to the importance which they give to production operations. In uncertain and complex markets, companies must make their operations cheaper without sacrificing any quality to be able to increase their profit ratio in spite of gradual increases in competitive pressure. One of the biggest shares in total costs is inventory. Companies are obliged to consider the issue of inventory management. For effective inventory management, many inventory control methods have been developed and EOQ is at the forefront.

Excess inventory raises costs and causes losses to companies. However, for various reasons, companies must have excess inventory. In this study, some of the reasons for having inventory in the ceramic factory are that some products are used both in production and sold in the domestic market as well as the preparation surface, demands of some orders which come in the form of projects very variable demands, machine failure, machine maintenance and changes in production plan due to interruptions in production. Due to these reasons, inventory costs of the company will rise. The most effective method to reduce the inventory cost of the company is the EOQ model.

Companies will be able to manage their inventory better and to increase their profitability by using the EOQ model more frequently and widely. Therefore, companies will have an advantage over their competitors.

One of the most important conclusions which can be made from this study is that the EOQ model is one of the most important tools which is still valid today. Better improvements were observed by using the EOQ model for the ceramic factory inventory. If companies are more sensitive to the EOQ model topics, they will be able to use it better and more frequently. As a result, companies will keep their inventory optimum and reduce their inventory cost.

An effective model for inventory control may not always be created due to major reasons such as; sudden changes in customer demands and needs, the company's exceptions, market conditions and demand uncertainty due to changes in production and sales. In such conditions, the response surface method can be effectively used.

EOQ calculation results found by establishing a model and RSM calculation results are very close each other. It may be easier and simpler to calculate with RSM rather than conducting different studies regarding demand forecasting in EOQ calculations. The ceramic factory did not conduct a study regarding demand forecasting in every new period so it could not reach the top spot in EOQ analysis. Studies which are conducted by establishing a model cause more loss of time and difficulty, so companies will gain time and as well as speed with the RSM.

In this study, for the case ceramic company, economic order quantity for the ceramic factory was calculated again and the values which the company applied and the obtained results were compared. The evaluation results show that the company's inventory costs will rise as the EOQ value of MKRK, CS, GKOM, AOM, STFA, GZZM, FZZF, SCCPA, PN, SLSB, CO.95, EP, FMSR, SPAT, STCAT, KTCAT and DNY products are high. The company will have run out of inventories stemming from EOQ values of CO.99, AB, BPE, AOS and DNY products which are lower than required. Changes in production plans which stem from absence of inventory occur due to these products. In the first case, the company's inventory costs will increase. In the second case, there will be some delays in the production of certain orders; hence the products will be delivered late to customers, so customer dissatisfaction is likely. In addition, due to the reasons such as changes in the production plan and changes in machine molding and machine settings, delays will increase, and these conditions will increase costs to the company. In both cases the cost to the company increases and more details about these could be gathered from [19].

A study which was conducted by Mahfuz, Shahrul and Islam [20] in a pharmaceutical factory shows that the inventory levels of the EOQ model can be optimized. Spare parts inventory management and inventory optimization work was completed by using the EOQ model by Lair, Muhiddin, Laudi, Tamiri and Chua [21]. In this study, we showed that there are big differences between the EOQ value which is applied by the company and EOQ values which we calculated. The company will obtain a large gain of around 5914 currencies as a result of inventory optimization.

Calculations of the EOQ and the RSM will provide simplicity in terms of many aspects for companies. The advantage of conventional EOQ is that it can be easily calculated with a simple formula without the need for any equipment. The disadvantage of conventional EOQ is; the use of on demand forecasting in calculations, the lack of accuracy of this forecast, the timeconsuming calculations, and inability to test the reliability of the result. The advantages of the RSM approach is that it is able to be done more quickly, without the hassle of dealing with more practical, useful, demand forecasting methods. Disadvantages of the RSM approach are that it uses only historical data in calculations, and calculations are not dependent on economic and social effects other than business. These are the limitations of the RSM calculations.

Companies will be able to do the EOQ calculation in a more practical, useful and fast way without dealing with demand forecasting methods and errors. Also, we can test the reliability of the results found by using RSM program on a computer. When we want to analyze the EOQ by establishing a model, we first need to determine the demand. To do this, it requires demand forecasting analysis by using available data. Calculations are made for a model by picking the best results in forecasting analysis. The degree of confidence in the value that was obtained from the calculations may not be measured. As a result of this work, these results and calculations are an alternative way of dealing with conventional EOQ calculations.

Calculations of EOQ and RSM will provide simplicity in terms of many aspects for companies. In brief, the calculations with only conventional EOQ do not satisfy the expectations of manufacturing companies nowadays. From this point of view, an alternative approach was presented to solve this problem. In this study, for the case company, the use of conventional EOQ approach leads to the company keeping high-level inventory, while the proposed approach advises lower inventory levels. Thus, the company may use the storage area more economically and increase economic profit with lower inventory

References

[1] Selcuk O., *Examining inventory control methods and a practice in construction materials sector*, Master's thesis, Istanbul Technical University Graduate School of Science Engineering and Technology, Istanbul, 2007.

[2] Yaman R., *Production planning: control and integration*, Nobel Publisher 1th press, 25-180 Ankara, 2011.

[3] Roach B., *Origins of the Economic Order quantity Formula*, Washburn University School of Business Working Paper Series, Kansas, 2005.

[4] Kucuk O., *Inventory management*, Seckin Publisher 2th press 21-137, Ankara, 2011.

[5] Teng J.T., *A simple method to compute economic order quantities*, European Journal of Operational Research, 351–353, 2009.

[6] Yu G., *Theory and methodology robust economic order quantity models*, European Journal of Operational Research, 482–493, 1997.

[7] Grubbstrom R.W., Erdem A., *The EOQ with backlogging derived without derivatives*, International Journal of Production Economics, 59, 529–530, 1999.

[8] Cardenas-Barron L.E., *The economic production quantity (EPQ) with shortage derived algebraically*, International Journal of Production Economics, 70, 289–292, 2001.

[9] Minner S., *A note on how to compute economic order quantity without derivatives by cost comparisons*, International Journal of Production Economics, 105, 293–296, 2007.

[10] Wee H.M., Wang W.T., Chung C.J., *A modified method to computer economic order quantities without derivatives by cost – difference comparisons*, European Journal of Operational Research, 194, 336–338, 2009.

[11] Zipkin P.H., *Foundations of inventory management*, McGraw-Hill, 2000.

[12] Heızer J., Render B., *Operations management*, New York, Prentice Hall, 2001.

[13] Stevenson W.J., *Production & operations management*, Irwin Publishing, 536, 1996.

[14] Box G.E.P., Draper N.R., *Empirical model building and response surfaces*, John Wiley and Sons, New York, 1987.

[15] Myers R.H., Montgomery D.C., *Response surface methodology process and product optimization using designed experiments*, New York, 2002.

[16] Jurado E., Camacho F., Luzon G., Vicaria J.M., *A new kinetic model proposed for enzymatic hydrolysis of lactose by a β- galactosidase from Kluyueromycesfragilis*, Enzyme and Microbial Technology, 31, 300–309, 2002.

[17] Kan B., *MARS approach to response surface models*, PhD thesis, Anadolu University Graduate School of Science Engineering and Technology Statistic Division, January, 2011.

[18] Ciftci E., *A study on higher order response surface models*, Master's thesis, Hacettepe Technical University Graduate School of Science Engineering and Technology Statistic Division, Ankara, 2011.

[19] Yıldız R., *Examining the economic order quantity for certain product group in a production company*, Master Thesis, Balıkesir University Institute Of Science Industrial Engineering, March 2015.

[20] Mahfuz M.H., Shahrul I.M., Islam M.A., *Application of fixed time period model for optimizing inventory level: a case study in a pharmaceutical company*, Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Engineering e-Transaction, 2008, ISSN 1823-6379.

[21] Laır N.A.M., Muhiddin F.A, Laudi S., Tamiri F.M., Chua B.L., *The Spare Part Inventory Management System (Spims) for the profound Heritage SdnBhd: a case study on the EOQ technique*, International Journal of Research in Engineering & Technology, 2321–8843, 2014.