Supply Chain Insider

Volume 04, Issue 01
Article Received: 05-10-20
Accepted: 05-11-2020
Available Online: 15-12-2020
ISSN: 2617-7420 (Print), 2617-7420 (Online)
supplychaininsider.org

Minimization of Inventory for Higher Production Using Response Surface Methodology

Jannatul Fardush Shorna, Mashrur Fahim, Jannatul Ferdous Shorna, Mumtarin Rahman

Department of Industrial and Production Engineering, Military Institute of Science and Technology

Abstract

Supply chain management is the handling of the entire production flow of a good or service — starting from the raw components all the way to delivering the final product to the consumer. It depends hugely on the management of demand, production and inventory. The more accurately these parameters are handled, the more successfully the objectives of any business are achieved. A supply chain is considered efficient if the cost can be minimized applying the very analytical tools of the supply chain itself. To minimize the overall cost, minimizing the inventory cost has an impactful result. In this paper, we set the focal point at minimizing the inventory of a renowned company based on the LPG industry in Bangladesh. Applying the Response Surface Methodology (RSM) first the production error and forecast error have been found out. The aim was to determine the most reliable forecasting method that would minimize the production error and inventory error at the same time. At the end of our experiment, we could discover that Trend Analysis perfectly fit the objective of this work.

1. Introduction

In today's fast pacing world, Supply Chain Management is an integral part of most of the businesses and is the key to company success. The more balanced supply chain a company holds on to, the more efficient its outcome will be. Supply chain revolves around three parameters which are demand, production and inventory. These parameters are interrelated and in case any one of these is affected results in affecting the other two. If demand rises, the production has to be increased and as a result will create an impact on inventory; on the contrary if demand lessens, that too will result in some shifts in the amount of production

as well as inventory. The aim of any company follows the minimization of cost; which generally indicates minimizing production and inventory cost as the rest of the costs associated are almost of a certain range but these differ according to amount but can be controlled if managed sincerely.

In this paper we focused on one of the leading companies based on the LPG industry in Bangladesh holding on to 25% of the total market share. Generally, they receive demand of a certain range, following which production is carried out and the same time inventory is managed. But for the ongoing pandemic of the coronavirus disease 2019 (COVID-19), they faced huge difficulties maintaining their inventory cost as the circumstances led to complications balancing between demand and production. As a result, it caused the company to struggle determining the accurate rate of production which further had a great impact on not only their inventory but also inventory cost. So, obtaining necessary data which includes demand per month, production per month from the company we aimed at minimizing inventory using Response Surface Methodology (RSM). The method was introduced by George E. P. Box and K. B. Wilson in 1951. [1] RSM is a widely used mathematical and statistical method for modeling and analyzing a process in which the response of interest is affected by various variables and the objective of this method is to optimize the response. [2] There are basically a few forecasting methods used for such issues which include Moving Average, Trend Analysis, Time Series Decomposition, Single Exponential Smoothing and Winter's Method. The objective is to determine production error and forecasting error and finding out which method of forecasting leads to minimize both at the same time; which will eventually result in predicting the nearest accurate amount to be produced and kept in inventory thus minimizing inventory level.

2. Literature Review:

Inventory management and demand forecasting has been an important issue and a challenging problem in supply chain management. For this there have been several studies on the data mining and RSM (Response Surface Methodology). The various organizations have started realizing its importance therefore literature regarding inventory and demand forecasting. The literature on various facts of inventory and demand have been discussed in Table 1.

Response Surface Methodology:

This Paper we minimize the inventory cost with respect to production per month by using RSM in Minitab. Response surface methodology (RSM) is a group of mathematical and statistical techniques used to describe the relationships between a response of interest and a number of associated control (or input) variables denoted by x1,x2,x3….xn [1]. The most extensive applications of RSM are in cases where several input variables potentially influence some performance measure or quality characteristic of a process. Thus, performance measure or quality characteristic is called the response. The objectives of RSM include the determination of variable settings, for which the mean response is optimized, and the estimation of the response surface. In general, such a relationship is unknown but can be approximated by a low degree polynomial model of the form,

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \beta_{ii} X_i^2 + \sum_{i<j} \sum \beta_{ij} X_i X_j + \varepsilon \quad \text{……. (1)}$$

In equation (1) Y is the response, n is the number of independent variables, j =1, ..., n , β0 is the constant term, βi represents the coefficients of the linear terms, βij represents the coefficients of the interaction terms, βii represents the coefficients of the quadratic terms, and ε is an error term. The expected value of Y represents the response surface that can be used to approximate the mathematical relationship.[3]

Some stages in the application of RSM are [2]

- The selection of independent variables of major effects on the system through screening studies;
- The choice of the experimental design and carrying out the experiments according to the selected experimental matrix; The mathematic and statistical treatment of the obtained experimental data through the fit of a polynomial function;
- The evaluation of the model and fitness;
- The verification of the necessity and possibility of performing a displacement in direction to the optimal region;
- Obtaining the optimum values for each studied variable between the system response and the independent variables affecting this response.

Table 1

Literature Review

Year	Title of Paper	Author	Methodology	Conclusion	Scope of future work
2007	Response surface methodology for constrained simulation optimization: An overview	Jack P.C. Kleijnen	**GSRM** methodology used to allow multiple responses, selecting one response as their goal and others as constrained variables. Polynomial approximation with mathematical programming findings to estimate a better search direction.	This article provides the adapted steepest ascent (ASA) search directions which improves classic procedures. Also, a procedure for testing whether estimated optimum is truly optimal	Further work can be on investigation of GSRM and competing heuristics to a variety of practical simulation models.
2018	Modeling and Optimizing of variance amplification in Supply Chain using Response Surface Methodology	Ahmed Shaban & Mohammed Shalaby	The response surface methodology is presented showing how a mathematical model relating to supply chain response to the forecasting and inventory replenishment parameters can be obtained through integrated simulation and RSM.	This paper indicates the approach can achieve a comparable performance and that the integration of simulation modeling and RMS can be employed effectively and optimize dynamic supply chain.	Results suggest a further investigation of the characteristics of the function to customize efficient and analytical methods.

2009	Robust optimization in simulation: Taguchi and Response Surface Methodology	Gabriella Dellino, Jack P.C. Kleijnen & Carlo Meloni	Develops a robust simulation-optimization combining Taguchi's view of the world and RSM and illustrates the resulting methodology through classic Economic Order Quantity (EOQ) inventory models demonstrating that robust optimization may require order quantities that differ from the classic EOQ.	Taguchi's statistical techniques being replaced by RSM generating the application of the new methodology to the classic EOQ model that results in a good estimate of the true EOQ for a known environment and for an environment with a demand rate that has a known distribution—the classic EOQ and the robust EOQ differ.	Aims to adjust the proposed methodology for discrete-event simulation models that have aleatory uncertainty as well as apply to complex supply chain models.
2015	A retail demand forecasting method based on data mining techniques	Irem Islek & Sule Gunduz Oguducu	This paper uses a moving average model and Bayesian network algorithm to provide appropriate demand forecasting by overcoming limitations.	This work represents an approach for demand forecasting which can handle numerous distribution warehouses and products.	Further work can be done on a separate model application to the sub warehouse of this main warehouse providing better results.
Year	Title	Author	Methodology	Conclusion	Scope of future work
2014	Minimizing inventory cost for capacity constrained production using a Hybrid Simulation Model	John M. Betis	This paper uses hybrid simulation models and analytical expression for their research paper work.	This works represents the cost minimization target level when production is subject to a capacity constraint.	Further work can be stimulated because it refers to only a single discrete event.
1983	Optimization in Simulation Experiments Using Response Surface Methodology	M. Hossein Safizadeh & Billy M. Thornton	Helps the user to select an appropriate experimental design from the many types available by offering two tree diagrams which relate the objectives a simulation designer may have to the various experimental designs.	The particular work presents two tree diagrams to help in the choice of an experimental design along with presenting in detail the application of RSM to a typical problem stated early in the paper.	The experiment apparently eliminated the need for blocking but blocking within a different context may increase the efficiency of simulation results - which leads to work on further negotiating circumstances.
2004	Forecasting demand and inventory management using Bayesian Time Series	T.A. Spedding & K.K. Chan	A Bayesian dynamic linear time series model is proposed as an alternative technique for forecasting demand in a dynamically changing environment.	The work done on the paper can cope up with the structural change of the time series data significantly improving the accuracy of the predicted demand.	Future work includes subjective intervention on system behavior carried by expert knowledge

2018	Modeling throughput in production lines using Response Surface Methodology and Artificial Neural Network	Joselito Medina-Marin	Response surface methodology and artificial neural network were used to develop predictive models to find optimal throughput value. 360 experimental data were used.	In this paper the throughput in production lines was accurately modeled with RSM and ANNs.	As further work, this ANN model can be used to find optimal or near optimal values of the throughput for minimal number of buffer slots between each machine in the system, in order to minimize the total buffer size.
	A Dynamic Forecasting and Inventory Management Evaluation Approach	Johannes Fichtinger, Yvan Nieto and Gerald Reiner	Used a two-stage supply chain model to show the supply chain performance in terms of on-hand inventory, fill rate and bullwhip effect along with using the efficiency frontier approach to provide a single performance measure and further analyses our results.	For the stationary demand case that as long as the number of periods is sufficiently large and it has no noticeable effect on the performance of the supply chain however considering non-stationary demand caused by misspecification of the price dependency.	Each input needs to be linked to limits and weights related to the specificity of the supply chain under study in order to provide more realistic evaluation.

3. Results

Numerical Experiments:

The data used in this article are obtained from one of the leading manufacturing companies in Bangladesh. In this article we analysis the data weather these data are fitted our purpose or not. Find out the optimal forecasting method by comparing one method to another and minimize the inventory by using RSM (Response Surface Methodology)

Regression Analysis:

Table no: 01

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2578	7488	0.34	0.735	
Demand per month	-0.8280	0.0905	-9.15	0.000	3.13
Production Per Month	0.8127	0.0733	11.09	0.000	3.13

Table no:01 shows the p value for both demand per month and production per month are significant (p value < significance level (0.05)) and constant value is insignificant.

Table no: 02

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
488.137	87.85%	86.42%	*

Table no:02, Represents the data in the fitted line plot following a low noise relationship, and the R-squared is 87.85%, which means a regression model very well fits this data set. This statistic helps to identify this data where the model provides a good fit for the existing data but isn't as good at making predictions. On the other hand, R-sq.(ad) value 86.42% represents input variables and adding variables after regression are suitable

Figure no: 01

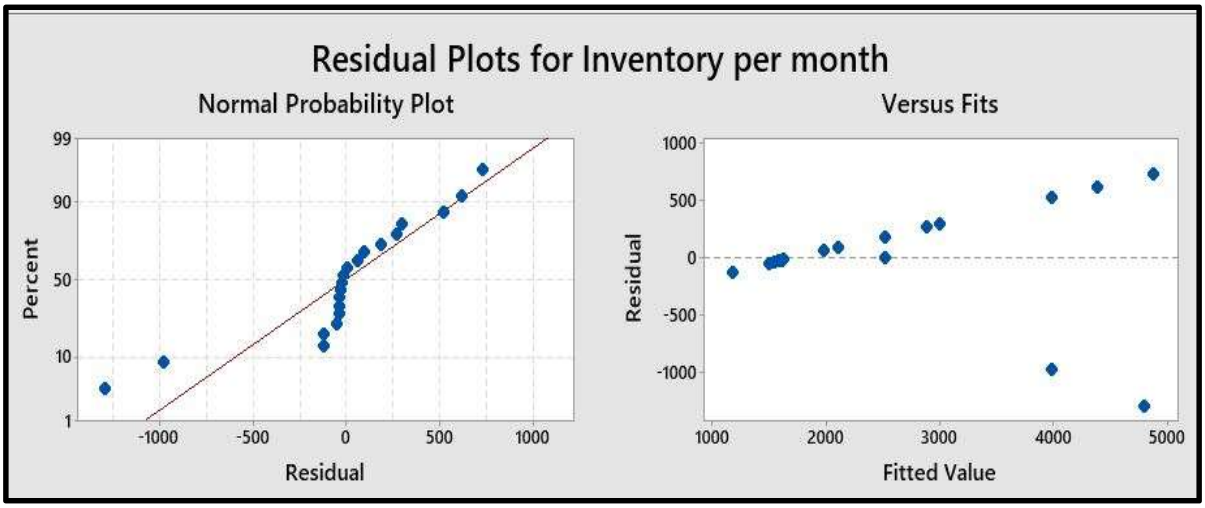


Fig 01, A straight diagonal line in a normal probability plot indicating normal distributed data and from right to left side two data point shows are not normal distribution. Versus Fits data shows overfitted here.

Correlation Coefficient Analysis:

The results of the analysis give an outcome which indicates the strong relationship among inventory per month and production per month [Table no: 04] where inventory per month and demand per month [Table no: 05] can't maintain the strong relationship. So, we came to the conclusion that minimizing the inventory cost, production has the significant effect.

Table no: 03

Correlations

	Inventory per month
Production Per Month	0.529

Table no: 04

Correlations

	Inventory per month
Demand per month	-0.001

Forecasting Method Comparison:

Inventory and Product Forecasting:

Five forecasting methods applied for Inventory Per Month forecasting and Product Per Month forecasting. Three types of forecasting error: Mean Absolute Percentage error (MAPE), Mean Absolute Deviation (MAD), Mean Squared Deviation (MSD) is measured whose value is analysed in table no:06 and table no:07

Inventory Per Month:

Table no:05

Forecasting Method	**MAPE**	**MAD**	**MSD**
Trend Analysis	31	732	1101964
Moving Average	52	1130	1643074
Single Exponential Smoothing	53	993	1913558
Winter's Method	52	996	1640362

Production Per Month:

Table no:06

Forecasting Method	**MAPE**	**MAD**	**MSD**
Trend Analysis	1	1507	6878349
Moving Average	1	1709	7270690
Single Exponential Smoothing	1	1730	7231524
Winter's Method	2	3285	16981066

Selection of Method:

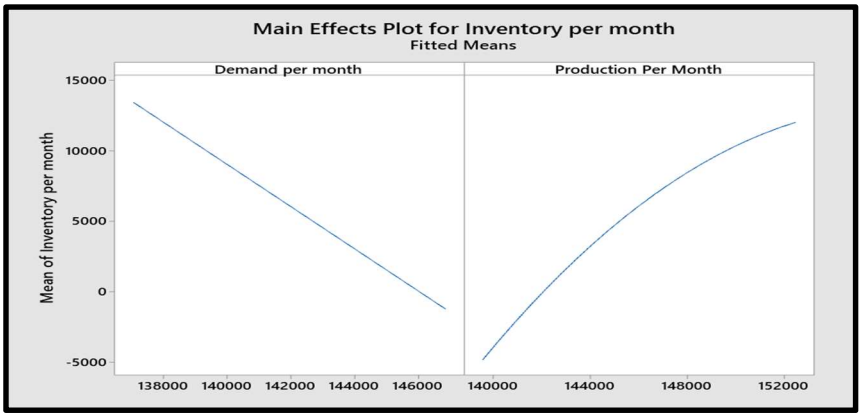
Table 5 compares MAPE, MAD, MSD of inventory per month and Table 7 compares MAPE, MAD,MSD of production per month for four different methods. The forecast errors are relatively small and acceptable for both production and inventory per month in trend analysis. Thus, trend analysis is preferred for forecasting according to the collected data.

Statistical analysis for Response Surface Methodology:

Factorial Plot Analysis:

fig 02 interpreted the relationship in between both inventory per month Vs demand per month and production per month. Inventory decreases with respect to increase the number of demands. On the contrary, inventory per month increases with increasing the number of productions per month. Thus, the interpretation shows the accuracy of the data set.

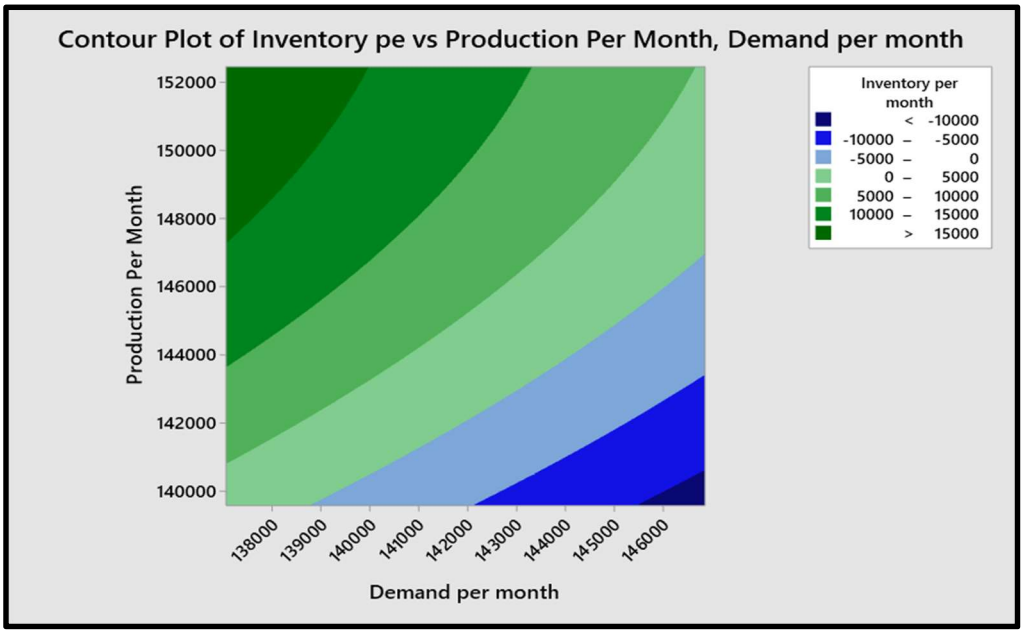
Figure no: 02



Counter plot Analysis:

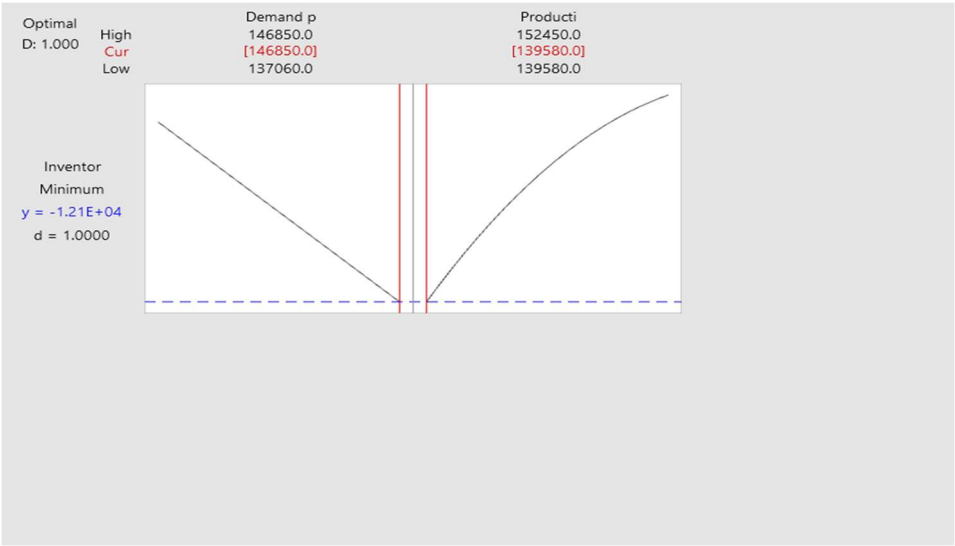
Production per month need to maintain 147900-152000 for getting more response minimized inventory. If the range of production per month in between 144000 - 152100 the resulted inventory will be significant and minimize but less than 147900-152000 range.

Figure no: 03



Minimization of Inventory:

Table no: 04



The optimal values of demand and production per month are 146850 and 139580 that minimizes the response inventory per month which is the main objective of this paper.

4. Conclusion

Response Surface Methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. Statistical approaches such as RSM can be employed to optimize operational factors. For formulation optimization, the RSM, using proper design of experiments (DoE), has become extensively used. In contrast to conventional methods, the interaction among process variables can be determined by statistical techniques. [1]

Supply Chain Management (SCM) is an important part of every organization, whether small or large. SCM is the active management of supply chain activities to maximize customer value and achieve a sustainable competitive advantage. SCM also deals with the movement and storing of materials needed to create a product, as well as inventory management, and keeping track of finished goods from where they were created to who they go to. Supply chain management has a huge impact on business. The right product and the correct quantity must be delivered in a timely manner, to appease both producers and distributors. To do so optimizing inventory is a must. [2]

Every company has the challenge of matching its supply volume to customer demand. How well the company manages this challenge has a major impact on its profitability. Inventory optimization seeks to more efficiently match supply to expected customer demand. The amount of inventory held has a major impact on available cash. With working capital at a premium, it's important for companies to keep inventory levels as low possible and to sell inventory as quickly as possible. [3]

In this work a leading company was focused on to resolve their issues raised due to the ongoing COVID-19 pandemic. They generally received demand of a certain range which was hampered by the global pandemic and obstructed the balance between demand and production. To overcome the difficulties, they needed to optimize their inventory. Using RSM we found our inventory error and production error. Trend Analysis led to resolve the issues by minimizing both the errors at the same time thus directing towards minimizing inventory.

Here the sample size used is smaller related to other relevant studies' which may lead to variation in results in case of huge sample size. On the other hand, we analyzed inventory basing on production mainly which may differ if it were analyzed basing on demand. Further work will be carried on to resolve the stated issues.

Acknowledgement

We would like to thank all reviewers for providing me very beneficial comments to help completing the analysis. I also thanks Lec. Doulatuzzaman Xames and Mashrur Ashker, Assistant Executive Engineer, Supply Chain, Bashundhara Group.

References:

- https://en.wikipedia.org/wiki/Response_surface_methodology
- https://en.wikipedia.org/wiki/Regression_analysis
- I. Khuri and S. Mukhopadhyay, "Response surface methodology," *Wiley Interdisciplinary Reviews: Computational Statistics*, vol. 2, no. 2, pp. 128–149, 2010.
- M. A. Bezerra, R. E. Santelli, E. P. Oliveira, L. S. Villar, and L. A. Escaleira, "Response surface methodology (RSM) as a tool for optimization in analytical chemistry," *Talanta*, vol. 76, no. 5, pp. 965–977, 2008.
- Myers, R. H., Montgomery, D. C., Anderson-Cook, C. M., 2016. Response surface methodology: process and product optimization using designed experiments. John Wiley & Sons
- G. Boente, D. Rodriguez, Robust estimators of high order derivatives of regression functions, Statistics and Probability Letters, in press.
- H. J. Brightman. Optimization through experimentation: applying response surface methodology. ***Decis. Sci.*** 9(3), 481495 (1978)
- D. S. Burdick & H. N. Thomas, Response surface techniques in economics. ***Rm. Inr. Srorisr. Insrir.*** 1, 18-35(1969).
- E. R. Clayton, B. J. Cooley & E. C. Houck, The application of RSM to an investment simulation. ***Am. Insrir. Decis. Sci. Proc. 2, 176-178 (1979).***
- Myers, R. H., Montgomery, D. C., Anderson-Cook, C. M., 2016. Response surface methodology: process and product optimization using designed experiments. John Wiley & Sons.
- Gocken, M., Dosdogru, A. T., Boru, A., 2017. Optimization via simulation for inventory control policies and supplier selection. International Journal of Simulation Modelling, 16(2), 241-252.
- Costantino, F., Di Gravio, G., Shaban, A., Tronci, M., 2015b. A real-time SPC inventory replenishment system to improve supply chain performances. Expert Systems with Applications, 42(3), 1665–1683.