Vol. XI & Issue No. 10 October - 2018
INDUSTRIAL ENGINEERING JOURNAL

OPTIMIZATION OF BLOOD SUPPLY CHAIN USING TAGUCHI ORTHOGONAL METHOD: A CASE STUDY OF M Y HOSPITAL

A. Aglecha
R. Nagaich

ABSTRACT

Blood supply chain has primary objective of ensuring availability of human blood to patients in a safe manner as and when it is required. Although medical science has seen many advancements but there is no substitute of blood has been produced so far. Any shortage in blood supply leads to human death. The purpose of this paper is to implement Taguchi method in blood supply chain to increase velocity of supply chain. Maharaja Yeshwantrao (M. Y.) Hospital, blood center Madhya Pradesh (India) has been selected as the case of study. In this paper, four controllable factors "arrival rate of donors", "maximum inventory level", "minimum inventory level" and "blood delivery policy" and one noise factor "demand variability" have been chosen. To achieve robust blood supply chain, optimization of all factors is done by ANOVA software. The optimum level of arrival rate of donors should be low i.e., 50 and minimum inventory, maximum inventory and blood delivery policy level should be high i.e., 120, 800 and LIFO respectively. Optimum level is defined for maximizing the efficiency of patient safety in blood supply chain.

KEYWORDS: Blood supply chain, dynamic simulation, Taguchi method, patient safety, signal-to-noise ratio.

1. INTRODUCTION

The blood supply chain commences with the blood donor and ends with the patient, but ultimately it is the requisite for blood by the patient that drives the chain, therefore, the number of blood donations required. Different factors affect the blood supply chain; the number of donors who are donated customarily, seasonal factors affecting blood donation e.g., national holidays, the blood services facility to adequately predict the number of units of blood required throughout the year and to make sure that they do not overstock, consequently, increase wastage, the clinicians' vigilance of opportune blood authoritatively and transfusion and the hospital laboratories faculty to ascertain ample stock yet have minimal wastage. It is mandatory for all staff working in each area of the blood supply chain aware of their responsibilities to ascertain minimal wastage of this freely given resource. Hence, education, training, and data accumulation are significant elements of the blood supply chain.

Despite consequential advancements in medicine, human blood is still a scarce resource. Only human produce it and there is currently no other chemical process that can be used to generate blood; Therefore, blood is an essential item in healthcare systems. Since blood is additionally a perishable product, its inventory management is arduous. The challenge is in holding enough stock to ascertain a high caliber of supply while keeping losses from expiration at a minimum. This research will explore blood inventory management in a hospital and develop a mathematical model to control blood ordering and issuing. This study will responsible for the fact that blood demand and supply are uncertain. The proposed model accepts the substitution relations among various blood types in the blood transfusion process to reduced blood shortage and wastage [1].

A productive compatibility of blood supply and demand is not straightforward; aside from this, any deficiencies and impediments in blood supply prompt people's demise [2]. As for these troubles, blood supply chain management is of a challenge for regimes' healthcare systems. In addition, it will be more entangled thinking about the perishability of blood items, other than the way that blood outdates imposes high wastage cost since blood donors are scarce precious resources.

The blood supply chain is sequential processes of accumulating, testing, processing and distributing blood and blood products, from donor to recipient. Blood products are transfused to patients as a part of routine medical treatments or surgical operations and additionally in emergency situations. This denotes that availability of the right blood products is critical, since lives can be lost if no stock is available when it is needed; concurrently, blood is accumulated from human beings, and the blood donation rate varies across different countries [3]. According to the American Red Cross (2014) in the US, only 10% of all eligible people authentically donate blood, and the World Health Organization states that the figures for middle and low-income countries are considerably lower (WHO 2014).

Simulation modeling evaluates the procedures and outcomes of such supply chains and defines alternatives which can lead to improved performance. This method offers a reliable approach to study [4].

The objective of this paper is optimization of blood supply chain using Taguchi orthogonal method and to design a robust blood supply chain system. Optimum level is defined for maximizing the efficiency of patient safety in blood supply chain. Maharaja Yeshwantrao hospital (Madhya Pradesh, India) has been selected for carrying out this study.

2. LITERATURE REVIEW

In the last ten years, many projects on supply chain were done to analyze how firms increased processes, technology, and information for a supplier and customers. Most projects were done on strategy of supply chain design, planning, and their operations [5]. Anna Nagurney, Amir H. Masoumi, and Min Yu (2012) developed generalized network optimization model for the complex supply chain of human blood and determine the optimal allocations. They also fulfill uncertain demand as possible [6]. Yi-Chang Li and Hung-Chang Liao (2012) design a robust blood supply chain system considering the total cost (TC) and the safety of patients. A neural network (NN) and genetic algorithm (GA) techniques are used to determine the results [7]. Applications of operational research in healthcare are fully discussed by Papageorgiou (1978) and Rais and Viana (2010) [8-9]. Syam and Côté (2010) proposed a model for location-allocation of specialized healthcare systems [10].

A lot of research work is done on Taguchi method for process optimization but application of Taguchi method in blood supply chain is limited. Sachin Ashok Sonawane and M.L. Kulkarni (2018) was used Taguchi method for optimization of machining parameters of Wire Electrical Discharge Machining (WEDM) for Nimonic-75 alloy. Analysis of principal component is used to optimize the machining parameters [11]. Nesredin Chekole and Vivek Deshpande (2018) selected the optimum parameters for cylindrical grinding process optimization. They used the Taguchi method for optimization [12]. Mohamed Aslam Patel and D P Tambuskar (2017) has been applied the Taguchi method to optimize the machining parameters during end milling of Ti6Al4V. According to them, this method was quite successful to identifying the most dominating factors like cutting speed and feed rate [13].

3. MATERIAL AND METHODOLOGY

The Taguchi method for experimental design is easy to apply to many engineering problems as it allows the analysis of many parameters without high amount of experimentation. It helps in identification of key parameters that affect the performance and the parameters that have little effect are neglected. Taguchi method is mainly used to minimize the effect of noise factors and to achieve optimal result of controllable factors [14]. Taguchi technique creates a standard orthogonal array to evaluate the effects of design parameters on the response value [15]. Number of experimental runs can be minimized by the orthogonal arrays, so that the entire experiment will be reduced [16]. Using Minitab Software, we find the optimum level of all controllable factors. The signal to noise ratio (SNR) is the response (output) of the experiment. To obtain the result of simulation data, following two steps are used in Taguchi method.

3.1. Design Parameters with Their Levels

The control factors in this research are 'arrival rate of donors' (A), 'minimum inventory level' (B), 'maximum inventory level' (C), 'blood delivery policy' (D) each having 2 levels, high and low, as per the range of values they are most significant within as shown in Table 1. The noise factor is demand variability and efficiency parameter is patient safety.

Table1. Factors sampling range

Level	Factors			
	Arrival rate of donors (A)	**Minimum inventory level (B)**	**Maximum inventory level (C)**	**Blood delivery policy (D)**
Low level (1)	50	45	500	FIFO
High level (2)	150	120	800	LIFO

FIFO = first in first out

LIFO = last in first out

3.2. Choosing the Taguchi orthogonal array

An L8 orthogonal array is utilized to study the effects of control factors on the response. The whole design is replicated twice to minimize the experimental error and a total of 8 runs were obtained.

4. RESULT AND DISCUSSION

4.1. Performing Simulation Experiments and Data analysis:

The signal to noise ratio can be basically understood as the ratio of signal factor to the noise factor in the experiment. As per the goal of the optimization, signal to ratio can be decided to be maximized, minimized or kept at nominal value. It helps in choosing the control levels that can compensate the effects of noise to the maximum [17]. Here, signal to noise ratio is chosen to be kept the maximum, as the goal of the design is to maximize the efficiency. The aim is to maximize the effect of noise factors on the response. The calculation of signal to noise ratio is based on the situation "Larger is better" [18]. In this case, we use the formula given in Equation (1) for calculating the SNR. Table 2 shows the results of simulation experiments.

$$Z = -10\ \mathrm{Log} \frac{\sum_{i=1}^{n} \frac{1}{y_i^2}}{n}$$

Where, n=number of values in each experimental conditions and Yi =each observed value.

Table2: Analysis of the data produced by MINITAB software

No. of experiment	A	B	C	D	Response	SNRA
1	1	1	1	1	70	36.9020
2	1	1	2	2	85	38.5884
3	1	2	1	2	103	40.2567
4	1	2	2	1	117	41.3637
5	2	1	1	2	90	39.0849
6	2	1	2	1	91	39.1808
7	2	2	1	1	72	37.1466
8	2	2	2	2	94	39.4626
Average					90.25	38.9982

4.2. Main Effects Plot

Main effect is a value which shows the extent of influence of a factor on the response. Main effect plot represents the variation in the response variable with the variation in control factors and is used to examine differences between level means for factors. In a main effect plot, if the line plotted is horizontal, the factor is said to be insignificant since there is no change in response with the factor but if a line has high slope, it shows that the factor is significantly affecting the response [19]. Figure 1 show the effect of arrival rate of donors, minimum inventory level, maximum inventory level, blood delivery policy on signal to noise ratio.

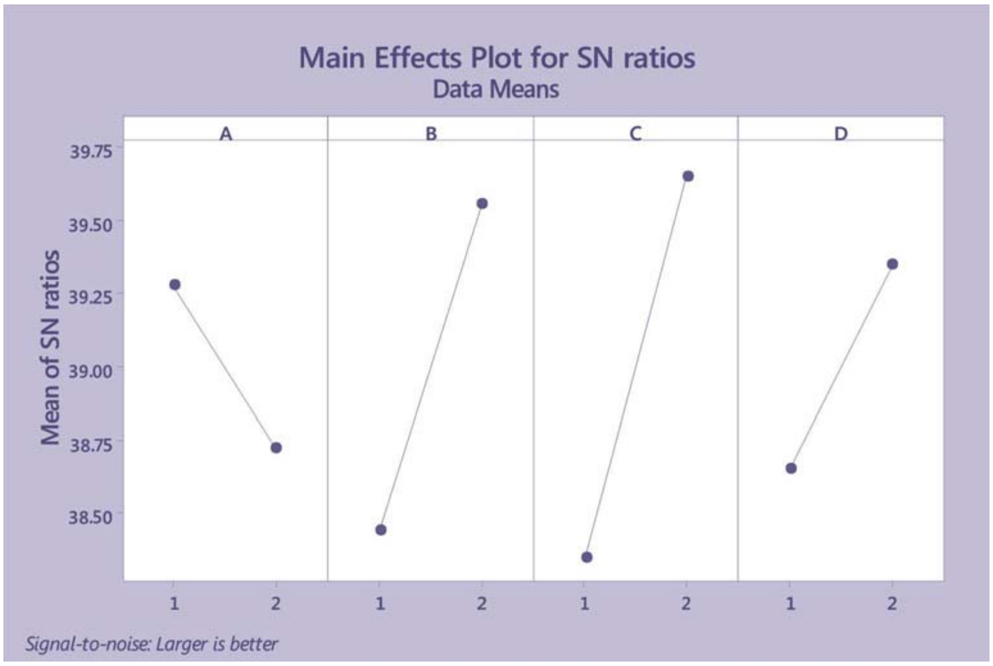

Figure1: Main effect plot for SN ratio

4.3. Determining the optimum condition

By evaluating the figures, it is easy to determine the favorable levels of control factors which should be chosen to get a robust design. We decide which factor level is selected to maximize the efficiency in blood supply chain. The signal to noise ratio (SNR) values at the both levels of each factor is compared. Figure 1 shows the Main effect plots for SNR; it shows that when factor arrival rate of donors placed on low level and factors minimum inventory level, maximum inventory level and blood delivery policy placed on the high level then optimum results of the controllable factor achieved.

4.4 Discussion

In this study, design of robust blood supply chain system is proposed. On the basis of the highest signal to noise ratio, identified optimal control factors of M. Y. hospital blood supply chain. Rank of all factors is obtained by using Minitab software based on their effect value. Compare signal to noise ratio values at both levels of all factor for deciding optimum level. Based on Taguchi experiment optimum level of arrival rate of donors is low i.e., 50 and minimum inventory, maximum inventory and blood delivery policy level is high i.e., 120, 800 and LIFO respectively. Optimum level is defined for maximizing the efficiency of patient safety in blood supply chain. Effect and ranking of signal to noise ratio for each controllable factor are shown in Table 3.

Table 3: Effect and ranking of signal to noise ratio for each controllable factor

Levels	Arrival rate of donors (A)	Minimum inventory level (B)	Maximum inventory level (C)	Blood delivery policy (D)
1	39.28	38.44	38.35	38.65
2	38.72	39.56	39.65	39.35
Delta	0.56	1.12	1.30	0.70
Rank	4	2	1	3
Optimum level	1	2	2	2

5. CONCLUSION

Given its major impact on patients' safety, developing an effective management of the blood supply chain appears to be the most important challenge for the future of transfusion medicine. Blood is a limited resource, so we need to efficient utilization of such perishable products in health care. Blood supply chain system is complex in nature; many uncertainties are in this system. Blood is essential substance for human life, without blood human cannot live; hence, we cannot use trial and error approaches to evaluate the significant effect of different factors. The purpose of this paper is to design a robust blood supply chain using Taguchi orthogonal method. To achieve a robust blood supply chain we decided the optimum level of factors. The final result shows that optimum level of arrival rate of donors should be low i.e., 50 and minimum inventory, maximum inventory and blood delivery policy level should be high i.e., 120, 800 and LIFO respectively. Optimum level is defined for maximizing the efficiency of patient safety in blood supply chain. Finally, blood supply chain is optimized using optimal parameters.

REFERENCES

1. A. Ahmadi and M. Najafi, Blood inventory management in hospitals: Considering supply and demand uncertainty and blood transshipment possibility, Operations Research for Health Care, Vol. 15, pp. 43-56, 2017.
2. Q. Duan and T. W. Liao, Optimization of blood supply chain with shortened shelf lives and ABO compatibility, International Journal of Production Economics, Vol. 153, pp.113-129, 2014.
3. A. F. Osorio et al., A structured review of quantitative models in the blood supply chain: a taxonomic framework for decision-making, International Journal of Production Research, Vol. 53, pp.7191-7212, 2015.
4. K. Katsaliaki and S.C. Brailsford, Using simulation to improve the blood supply chain, Journal of the Operation Research Society, 58, pp.219–227, 2007.
5. I. Sukati et al., The study of supply chain management strategy and practices on supply chain performance, Procedia - Social and Behavioral Sciences, Vol. 40, pp. 225-233, 2012.
6. A. Nagurney, A. H. Masoumi, and M. Yu, Supply chain network operations management of a blood banking system with cost and risk minimization, Computational Management Science, Vol. 9, pp. 205-231, 2012.
7. Y. Li and H. Liao, The optimal parameter design for a blood supply chain system by the Taguchi method, International Journal of Innovative Computing, Information and Control , Vol. 8, pp. 7697-7712, 2012.
8. J. C. Papageorgiou, Some operations research applications to problems of health care systems (a survey), International Journal of Bio-Medical Computing, Vol. 9, pp. 101-114, 1978.
9. A. Rais, and A. Viana, Operations research in healthcare: A survey, International Transactions in Operational Research, Vol. 18, pp. 1-31, 2010.
10. S. S. Syam, and M. J. Côté, A location–allocation model for service providers with application to not-for-profit health care organizations, Omega, Vol. 38, pp. 157-166, 2010.
11. S. A. Sonawane and M.L. Kulkarni, Optimization of machining parameters of WEDM for Nimonic-75 alloy using principal component analysis integrated with Taguchi method, Journal of King Saud University – Engineering Sciences, Vol. 30, pp. 250-258, 2018.
12. N. Chekole and V. Deshpande, Review analysis on optimization of cylindrical grinding process parameters by using Taguchi technique, Industrial Engineering Journal, Vol. XI, pp. 35-39, 2018.
13. M. A. Patel and D. P. Tambuskar, Multi-objective optimization of machining parameters during end milling of Ti6Al4V using extended Taguchi approach, Industrial Engineering Journal, Vol. X, pp. 29-34, 2017.
14. S. M. Zahraee et al., Application of statistical Taguchi method to optimize main elements in the residential buildings in Malaysia based energy consumption, Applied Mechanics and Materials, Vol. 606, pp. 265-269, 2014.
15. D. K. Kasdekar et al., Taguchi method and ANOVA: an approach for selection of process parameters of EDM of EN-353 Steel, International Journal of Emerging Technology and Advanced Engineering, Vol. 4, pp. 313-321, 2014.
16. A. R. Khoei et al., Design optimization of aluminium recycling processes using Taguchi technique, Journal of Materials Processing Technology, Vol. 127, pp.96-106, 2002.
17. N. S. Dhole, G.R. Naik, and M..S. Prabhawalkar, Optimization of milling process parameters of EN33 using Taguchi parameter design approach; Journal of Engineering Research and Studies, Vol. III, pp. 70-74, 2012.
18 S. Zandevakili et al., Synthesis of lithium ion sieve nanoparticles and optimizing uptake capacity by Taguchi method, Iran J. Chem. Chem. Eng., Vol. 33, pp. 15-24, 2014.
19. A. C. Mitra et al., Implementation of Taguchi Method for robust suspension design, Procedia Engineering, Vol. 144, pp. 77-84, 2016.

AUTHORS

Ajay Aglecha, M.E., Industrial Engineering & Management, Ujjain Engineering College, Ujjain, M. P. India.
Email:- ajayaglecha1992@gmail.com

Prof. Ravi Nagaich, Department of Mechanical Engineering, Ujjain Engineering College, Ujjain India.
Email:- ravi.nagaich@gmail.com