International Research Journal in Global Engineering and Sciences. (IRJGES)
ISSN : 2456-172X | Vol. 5 Issue 4 - December 2020 to February 2021| Pages 33-41

# Productivity enhancement in manufacturing sector using Six Sigma

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## ABSTRACT

Modern organizations are in quest of initiatives that will facilitate them to be sustainable as well as provide a competitive advantage to remain a continuous stakeholder in the global market. Six Sigma SS is an all-inclusive methodology that assists the optimal utilization of resources, minimizes waste, and imparts the pathway for sustainable development. However, before implementing this comprehensive SS strategy, each organization needs to identify the barriers that are a hurdle to the execution of this approach. In the current research, sixteen barriers were recognized with the help of a systematic literature review and additionally authenticated by opinions of industrial personnel. The study reveals that lack of customer involvement is the most critical barrier. The identified SS barriers were further grouped into six critical barriers using Principal Component Analysis (PCA) based on the experts' opinions from industrial personnel. Thus, in this study, SS integration has been proposed based on intangible features like enablers, toolsets, etc. Management dedication, participation, and team effort have been recognized as the most remarkable enablers to implement this approach. Moreover, this study also proposes a five facet SS framework for the manufacturing sector to enhance organizational sustainability. Moreover, in the present work, SS tools and techniques have been used to identify and mitigate waste and enhance the proper utilization of resources. The present research work also proposes a novel five facet SS framework for the manufacturing industry to improve social and environmental sustainability along with economic one. The framework has been designed based on three key dimensions: Insights from literature, the experience of authors, and inputs from the case organization members. The framework is validated in an Indian automotive component manufacturing organization. Effective implementation of the suggested framework has assisted in a minimization of defects, level of rework, and environmental wastes, together with enhancement in functional and financial gain. The efficient execution of method 7S, Kanban, formation of proper plant layout, and Kaizen activities resulted in a minimization of the cycle time from 570 minutes to 440 minutes (22.80%). The environmental impacts were minimized from 44.70 Pt to 32.70 Pt contributing to 26.84% enhancement. Sigma level was also enhanced from 3.65 to 4.08. The present research work will encourage the organizations to have the willingness to the execution of a sustainable SS approach through a thorough knowledge of enablers, barriers, integration, and framework of SS.

***Keywords:*** *Six Sigma, Principal Component Analysis (PCA), 7S, Kanban, Kaizen.*

## 1.0 Introduction

Manufacturing industries are the key source for the development of the economy of any nation. This sector plays an important role to create employment and minimizing inequalities in the distribution of wealth that further assist to improvement in the national economy. The literature exposes that a 1% growth in the gross domestic product (GDP) will outcome in a 0.8% minimization in poverty, however, in developing country like India, 1% increase in GDP has noted only an insignificant 0.3% minimization in poverty. So, it is imperative to search for solutions that increase the operations dynamics of the manufacturing industries. The rapid economic growth connected with industrialization assists in an increase in capital formation, urbanization, increased utilization of natural resources, and alleviation of poverty and unemployment. The manufacturing sector is not deprived of challenges it faces challenges in all facets the sustainability. It is facing a huge challenge to cope with high production waste that leads to the non-optimal utilization of organization resources.

The prosperity of a country greatly depends on the best utilization of available resources for better productivity. Moreover, manufacturing industry is facing challenges pertaining to strict governmental policies on environmental emissions, sustainable product demands, and associated societal facets. It has been observed that industry contributes nearly 21% of the global GHGs emission.The concept of Six Sigma was invented in the 1980s by Motorola to minimize the variation in the process. To minimize the cost of a manufacturing system, lean minimize waste through withdrawing additional nature, but Six Sigma targets abolishing quality by reducing the defects. This concept was introduced by Motorola Company in 1987 and is widely applicable to all organizations. Six-Sigma is a greatly closely controlled approach, which is used to minimize variation in the process so that defects are minimized to less than 3.4 per million opportunities. Also, this is a business enhancement approach, which is used to search and minimize the reason for defects, process capacity waste, and errors in organizations. The six Sigma approach uses the DMAIC methodology that can be successfully applied to any project. Six Sigma methodologies minimize variation in a particular process but it is not able to minimize the waste in the production system. This approach minimizes process variation but does not reduce negative environmental impacts and related wastes in the process. Six Sigma is a business strategy and science that integrates statistical and business approaches that emphasize continuous and breakthrough enhancements to minimize the cost of the production, improve the satisfaction level of customers, and predictably produce high-quality products and services [a] [b]. It is a closely controlled approach that minimizes variation in the process so that defects are minimized to less than 3.4/M opportunities [c].

SS methodologies were not confined to enhancement impacts on the shop floor, but it also affected distinct aspects of manufacturing sectors [d] [e]. Schroeder et al. [f] dictated that SS group members employ advanced root cause analysis methods and acquire outstandingly more control and investigation concerning an issue compared to any other quality enhancement strategy. Mehrjerdi [g] determined SS DMAIC methodology application that included describing the problem to the control of the method to improve output.The key objective of SS is to attain the quality of products by enhancing the process and mitigating source causes of defects [h]. Antony et al. [i] presented an analysis of the status of SS execution in SMEs in United Kingdom. Management involvement and participation, connecting Six Sigma with customs and commercial approaches had been recognized as the most pre-eminent success factors for the execution of SS in SMEs. This method tries to estimate prevailing execution measurements and explores how the needed and optimal concert level could be accomplished [j].

## 2.0 Six Sigma - Performance Based Analysis

The questionnaire dependent survey has utilized to inspect validation of barriers identified by literature survey. Furthermore, a questionnaire-based survey was employed to present a association matrix for preparing modeling of SS barriers. This questionnaire was developed based on a rating from 1 to 5 in which 5 was marked as the strongest barrier which should be given first preference first while 1 being the weakest barrier and should be the least preference. This questionnaire was discussed with the industry experts and the academic experts. The experts were those who have the expertise in Lean, Six Sigma, and Green Manufacturing and are practicing the same in their vicinity. Therefore, sixteen SS barriers are identified in the comprehensive literature review. First, about 240 manufacturing experts of Indian industries were approached through email, mobile, and personnel visits to describe the SS concept in an organization. After a long discussion with the team, 130 out of 240 industrial experts (senior managers, managers, deputy managers, and senior engineers) have shown their interest in this study. So, 130 questionnaires were received, out of that 125 were further selected for analysis. Correspondingly, six academicians out of 13 decided to provide their feedback. To explore barriers concerned with executing the SS approach, a committed group of ten professionals was constituted. There were three senior managers in the supply chain field, two general managers of operation, one scientist from the environmental field, three professors from the Supply Chain Management (SCM) field and operations, and one professor experienced in environmental concerned issues. The experts chosen are greatly proficient in their areas and skilled in decision-making. All professionals having vast experience of more than 17 years in their domain were selected. To validate this questionnaire purposive sampling technique has been used in the present study. Moreover, the problem has been studied and discussed, then ISM technique was presented.

The formation of the ISM model is depended on circumstantial association among the final identified barriers. The relationship was established after doing brainstorming session with the various experts and discussing the detailed description of the identified barriers. Therefore, in this study, to certify this appropriate interrelation, two meetings with professionals were arranged. In the primary meeting, industrial authorities were requested to evaluate the significance and applicability of sixteen SS barriers that are recognized by SLR on the order of High- Moderate, and Low.

These ratings have been allocated to SS barriers from a systematic literature review and consult with the industrial personnel. High importance will be allocated to those critical barriers that play an imperative part in execution of this strategy. Moderate importance is given to barriers that have a medium effect on the execution of this strategy. Low importance will be allocated to those barriers that have less effect on the implementation of this strategy. In the second meeting, groups of professionals analyzed and talked out SS performance improvement barriers in further detail to certify appropriate interrelation of the "leads to" type. It replies that one barrier assists the other barrier. To fulfill the objectives of the current work ISM technique and MICMAC analysis have been employed as the research methodologies. It has been employed to establish the link between the recognized GLSS barriers and MICMAC has been applied to classify several groupings of barriers.

## 3.0 Interpretive Structural modelling of SS Barriers

It is a consistent methodology, accomplished subsequently the several phases of ISM are discussed below:

### Phase 1: Identification of several GLSS barriers

GLSS barriers were recognized by a literature survey and consulted with the industrial SS personnel. In the current study, 16 SS barriers have been recognized from an all- inclusive literature survey and by the opinion of the professionals.

### Phase 2: Development of Structural Self-Interaction Matrix (SSIM)

With help of an appropriate interrelationship among variables, SSIM is formulated which shows the pair-wise inter-relationship among the barriers.

X – Barriers i and j assist achieving one another, O – Barriers i and j are unconnected. The SSIM so formed is shown in the below table 1.

**Table 1: Structural Self-Interaction Matrix**

| S. No. | Barriers | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BR1 | X | A | O | V | V | V | V | O | V | V | Vz | V | X | X | X | V |
| 2 | BR2 | | X | O | V | V | O | O | O | O | O | V | O | A | X | A | V |
| 3 | BR3 | | | X | O | A | O | O | V | O | O | A | A | O | X | O | O |
| 4 | BR4 | | | | X | X | A | A | V | O | X | A | X | O | O | O | V |
| 5 | BR5 | | | | | X | X | A | A | O | X | A | X | V | O | X | A |
| 6 | BR6 | | | | | | X | X | O | X | V | X | V | V | X | X | X |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | BR7 | | | | | | | X | O | X | V | X | V | O | X | O | O |
| 8 | BR8 | | | | | | | | X | O | A | A | A | X | O | X | O |
| 9 | BR9 | | | | | | | | | X | V | X | V | O | O | O | X |
| 10 | BR10 | | | | | | | | | | X | A | A | A | X | A | A |
| 11 | BR11 | | | | | | | | | | | X | V | X | X | X | X |
| 12 | BR12 | | | | | | | | | | | | X | X | A | O | O |
| 13 | BR13 | | | | | | | | | | | | | X | X | X | X |
| 14 | BR14 | | | | | | | | | | | | | | X | X | V |
| 15 | BR15 | | | | | | | | | | | | | | | X | V |
| 16 | BR16 | | | | | | | | | | | | | | | | X |

**Phase 3: Initial Reachability matrix**

The reachability matrix is disintegrated to generate structural models. It is an algorithm-dependent process that dispenses for grouping of risks into various levels, contingent on their interrelationships. This dispenses a multilevel ISM model in which the relationship between risks is explained. The reachability matrix is formed by altering each entry into 1's and 0's (refer to Table 2)

For V- (i, j) entry will become 1, and (j, i) matrix will become 0 . For A- (i, j) entry becomes 0, and if (j, i) it will be 1

For X- (i, j) entry becomes 1 and for (j, i) will be 1

For O- (i, j) entry becomes 0 and for (j, i) will be 0

The 1* entry will be combined into initial matrix to fill the judgmental gap f any comes after discussing it with professionals. The final reachability matrix is formed based on the transitivity rule which we had already discussed previously.

**Table 2: Initial Reachability Matrix**

| BARRIERS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BR2 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| BR3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| BR4 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| BR5 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| BR6 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BR7 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| BR8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| BR9 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| BR10 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| BR11 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BR12 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| BR13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| BR14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| BR15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| BR16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 3: Final Reachability Matrix**

| BARRIERS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BR1 | 1 | 0 | 1* | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BR2 | 1 | 1 | 1* | 1 | 1 | 0 | 1* | 1* | 0 | 1* | 1 | 1* | 1* | 1 | 1* | 1 |
| BR3 | 0 | 0 | 1 | 1* | 1* | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1* | 1 | 1* | 0 |
| BR4 | 0 | 0 | 1* | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1* | 1* | 1* | 1 |
| BR5 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1* | 1 | 1 |
| BR6 | 0 | 0 | 1* | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BR7 | 0 | 0 | 1* | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1* | 1 | 0 | 0 |
| BR8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1* | 1 | 1* |
| BR9 | 0 | 0 | 1* | 1* | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1* | 1* | 1* | 1 |
| BR10 | 0 | 0 | 1* | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1* | 1* | 1 | 1* | 1* |
| BR11 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BR12 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1* | 1* |
| BR13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1* |
| BR14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| BR15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| BR16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Phase 4: Level Partition**

The level partition of the barriers will be done from the reachability set by examining the final reachability matrix which will consist of the barriers that it will achieve itself and another barriers. This will assist to attain others, the antecedent set which will consist of the barriers themselves and other barriers that it will assist in attaining, and intersection set will consist of the barriers which are common between the reachability and antecedent set.

**Phase 5: Formation of ISM based Model**

ISM model is formed with the help of a final reachability matrix called a digraph. SS barriers are classified into four quadrants according to their drive power and dependence power as given below:

- Autonomous barriers (Lower left quadrant): Autonomous types of barriers have a weak dependence power as well as weak driving power. No barrier falls in this quadrant in the current study.
- Driving barriers (Lower right quadrant): These barriers have strong driving power but weak dependence power. Lack of skilled training and knowledge, lack of higher management support, poor quality of raw material, absence of agreement among the employees, cultural barrier and communication gap, and lack of skilled technologies & proper manufacturing facilities are the driving barriers in the current study.

- Linkage barriers (Upper right quadrant): These barriers have strong dependence power as well as strong driving power. Internal resistance within the organization, in-efficiency of a regulatory framework, in-efficiency in transportation & material handling, ineffective strategies for implementation of SS approach, and lack in the use of manpower properly is the linkage barriers in the current study.
- Dependent barriers (Upper left quadrant): These barriers have weak driving power but strong dependence power. Not identifying the process parameters correctly, ignorance towards Kaizen, financial constraints, Ineffectiveness in the statical and visual control over SS execution, and lack of customer involvement are the dependent barriers in the current study.

## 4.0 Results and Discussion

On effective implementation of the SS approach by the proposed framework, the concerned industry was able to enhance its functional performance and ecological sustainability. Enhancements were perceived in the manufacturing process and ecological specifications by implementation of adopted SS framework. The enhancements perceived stated to lean measures like cycle time and process lead time. The efficient execution of method 7S, Kanban, formation of proper plant layout, and Kaizen activities resulted in a minimization of the cycle time from 570 minutes to 440 minutes (22.80%). Moreover, process lead time was also reduced from 16.7 days to 13.1 days (21.55%), which assists in a substantial saving in postponement of the final product. The applied enhancement activities fetched enhancement in the environmental measures of raw material consumption, water consumption, power consumption, and overall environmental impacts. Raw material consumption, power consumption, and water consumption were minimized by 19.35%, 18.66%, and 16.66% respectively. As there is a decrease in the principal resource consumption, a minimization in overall environmental impacts was also detected. The environmental impacts were minimized from 44.70 Pt to 32.70 Pt con 26.84% enhancement.

Furthermore, the methodical application of several enhancement methods carried significant enhancements in the prevailing capacity utilization of the plant by 19.80%. The sigma level of the considered industry was enhanced significantly by a minimization in the number of components rejected. Sigma level was enhanced from 3.65 to 4.08 (for a sample size of 1,000 parts the number of parts found defective was 7 and it is correspondence to the DMPO 7000 that was previously 18000). Table 6.8 represents the process parameters before and after the execution of the SS project in the considered industry.

## 5.0 Conclusion

The current research work probes the competence of Six Sigma to minimize production waste along with environmental emissions and improves economic and social facets of sustainability for the manufacturing sector. The conclusions drawn from the current research work are given below:

To meet the eco-friendly guidelines and consumer awareness about quality, therefore, the manufacturing sectors need to get knowledge about the relationship and characteristics of SS barriers. Sixteen barriers pertain to SS execution have been found suitable to be modeled and analyzed. Therefore, the ISM technique applies to establish the interrelationship between distinct SS barriers. The topmost level of the ISM model has barriers like lack of skilled training and knowledge and lack of higher management support. The most prominent barrier is the lack of customer involvement that rests at the bottom level of the ISM model. Modeling of such barriers motivates the industrial managers to acknowledge the mutual interrelationship and linkages of numerous barriers and that will consequent outcomes ineffective implementation of the SS approach. Furthermore, MICMAC analysis has been employed to classify these barriers into linkage, driving, and dependent barriers that will motivate the industrial managers and practitioners to achieve the objective of sustainable development. Five barriers are found as dependent barriers as well as linkage barriers. Six barriers are found as driving and there exists no barrier in the autonomous cluster.

**References:**


a) *V. Yadav, P. Gahlot, R. Rathi, G. Yadav, A. Kumar, and M. S. Kaswan, "Integral measures and framework for green lean six sigma implementation in manufacturing environment," Int. J. Sustain. Eng., vol. 14, no. 6, pp. 1319–1331, 2021, doi: 10.1080/19397038.2021.1970855.*

b) *B. M. Noone, K. Namasivayam, and H. S. Tomlinson, "Examining the application of six sigma in the service exchange," Manag. Serv. Qual., vol. 20, no. 3, pp. 273– 293, 2010, doi: 10.1108/09604521011041989.*

c) *A. Thomas, R. Barton, and C. Chuke-Okafor, "Applying lean six sigma in a small engineering company - A model for change," J. Manuf. Technol. Manag., vol. 20, no. 1, pp. 113–129, 2009, doi: 10.1108/17410380910925433.*

d) *R. Rathi, D. Khanduja, and S. K. Sharma, "A fuzzy MADM approach for project selection: A six sigma case study," Decis. Sci. Lett., vol. 5, no. 2, pp. 255–268, 2016, doi: 10.5267/j.dsl.2015.11.002.*

e) *A. Kumaravadivel and U. Natarajan, "Application of Six-Sigma DMAIC methodology to sand-casting process with response surface methodology," Int. J. Adv. Manuf. Technol., vol. 69, no. 5–8, pp. 1403–1420, 2013, doi: 10.1007/s00170- 013-5119-2.*

f) *A. Haikonen, T. Savolainen, and P. Järvinen, "Exploring Six Sigma and CI capability development: Preliminary case study findings on management role," J. Manuf. Technol. Manag., vol. 15, no. 4, pp. 369–378, 2004, doi: 10.1108/17410380410535071.*

g) *S. Fatemi and M. J. Franchetti, "An application of sustainable lean and green strategy with a Six Sigma approach on a manufacturing system," Int. J. Six Sigma Compet. Advant., vol. 10, no. 1, pp. 62–75, 2016, doi: 10.1504/IJSSCA.2016.080453.*
h) *Schroeder et al., "Six Sigma: definition and underlying theory," J. Oper. Manag., vol. 26, no. 4, pp. 536–554, 2008.*
i) *Y. Z. Mehrjerdi, "Six-Sigma: Methodology, tools and its future," Assem. Autom., vol. 31, no. 1, pp. 79–88, 2011, doi: 10.1108/01445151111104209.*
j) *P. Kumar, P. C. Tewari, and D. Khanduja, "Six sigma application in a process industry for capacity waste reduction: A case study," Manag. Sci. Lett., vol. 7, no. 9, pp. 423–430, 2017, doi: 10.5267/j.msl.2017.6.004.*
k) *J. Antony, M. Kumar, and C. N. Madu, "Six sigma in small- and medium-sized UK manufacturing enterprises: Some empirical observations," Int. J. Qual. Reliab. Manag., vol. 22, no. 8, pp. 860–874, 2005, doi: 10.1108/02656710510617265.*
l) *E. D. Arnheiter and J. Maleyeff, "The integration of lean management and Six Sigma," TQM Mag., vol. 17, no. 1, pp. 5–18, 2005, doi: 10.1108/09544780510573020.*