Chapter 8
Assessing Benefits of Lean Six Sigma Approach in Manufacturing Industries: An Indian Context

Vikas Swarnakar, Anil kr Tiwari, and A. R. Singh

Abstract Lean manufacturing objective is to eliminate the waste from the manufacturing process, and six sigma is grasping the variations within the process and tries to reduce them. Lean manufacturing or six sigma alone cannot improve the quality, customer satisfaction rate, net earnings and also cannot reduce the overall production cost of the organization, but the combined approach may solve these issues. Lean six sigma (LSS) is a combined approach which maximizes the overall value and minimizes the production cost by applying their tools and techniques such as VSM, JIT, 5S, Kaizen, and Kanban. The objective of this paper is to assess the benefits of LSS approach in a manufacturing organization. The data are collected through convenient sampling approach from manufacturing organizations situated in India and analyzed through integrated relative importance index and simple regression analysis approach. The findings of the study contributed to manufacturing industries and lay down a few suggestions for implementing lean six sigma in case manufacturing organizations. The three different manufacturing organizations considered performing this study. The study concluded that the implementation of LSS supports the case industries to improve their quality, cost, delivery, production capacity, net earnings, overall savings, customer satisfaction and reduce their defects, inventory, cycle time, and machine breakdown. The study helps LSS practitioners and academician to better understand the benefits observed while implementing the lean six sigma approach in manufacturing organizations.

Keywords Lean manufacturing · Six sigma · Lean six sigma · Manufacturing process · Relative importance index · Regression analysis

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8.1 Introduction

In the recent competitive market, manufacturing organizations are rapidly moving toward continuous quality improvement methodologies such as lean manufacturing (LM), six sigma (SS), and total quality management [1]. These methodologies are not new in nature. Continuous quality improvement thinking for any organization helps toward achieving the quality and overall operational performance [5]. Thus, every manufacturing organization needs to adopt such a quality improvement approach which provides long-term benefits with appropriately maintaining their product quality to achieve the leadership position in the market.

Lean manufacturing is a waste elimination approach and the concept of origin through Toyota Production System (TPS) by Taiichi Ohno after the Second World War during the 1940s. Lean manufacturing objective is to eliminate non-value adding activities, and different types of waste occurred during the production process. The waste is also called 'Muda' in the Japanese language. Authors introduced generally seven types of wastes occurred in organizations like overproduction, over-processing, unnecessary motion, waiting time, rework, inventory, and defects that occurred in the final product [6, 10, 19]. In addition to these seven wastes, two more new wastes 'underutilization of people knowledge' and 'environmental waste' have been suggested by the [15]. Lean manufacturing also reduces the cycle time and lead time of process [6, 7]. It has many tools and techniques such as 5S, Kanban, Kaizen, cause and effect analysis, and value stream mapping.

Six sigma is defined as a defect reduction strategy which grasps the variation from the process. It helps to identify and eliminate defects, failures in the system or process with the uses of their statistical tools. The adaptation of six sigma results in improvements in product quality, net savings, increases bottom-line results, increases customer satisfaction and reduction in cost, reduces defects, and brings them to 3.4 defects per million [16]. These can be achieved through their use of different tools and techniques such as quality function deployment, statistical process control, failure mode and effect analysis, design of experiments, analysis of variances, and Kano approach.

In fact, the adaptation of lean manufacturing alone cannot remove variation and controls the statistical process from system and implementation of six sigma approach isolation which cannot eliminate all types of waste from manufacturing process [13]. Therefore, to prevent such type of problem, organizations decided to integrate both approaches for continuous quality improvement. The integration of these two approaches provides effective benefits and improvement in key metrics faster than alone implementation. The concept of this approach was used in one company named George Group in 1986. This company is situated in the UK, and the term lean six sigma was first introduced in the literature in 2000 as an evaluation part of the six sigma approach [15, 16]. The increase in demand toward deploying LSS in their organization has been noticeable that time, especially large, medium, and small manufacturing organizations such as Motorola, General Electric, and Honeywell. [3].

This study utilizes the benefits of LSS adaptation in manufacturing organizations. In this context, the study was conducted in three different manufacturing organizations located within India. The case organization is suffering problems related to defects occurring in the finished product, and struggling to adapt continuous quality improvement approach which overcomes such problems and sustains the organization for the long run. The main aim of this study is to assess the key benefits of adopting LSS in a manufacturing organization and suggest these three case organizations for further implementation. To perform such work, the study collected the data from selected 52 already LSS adopted manufacturing organization situated within India. Based on the collected data from various manufacturing industries ranks the benefits. The further hypothesis was formulated and tested to check the validity of response related to LSS approach adaptation in manufacturing organization using a simple regression approach.

8.2 Literature Review

A systematic literature review has been performed in the context of LSS implementation in manufacturing organizations and identifies their benefits. This regards 19 lean six sigma literature has been reviewed from the Scopus database with a key search such as lean six sigma and lean six sigma benefits and found that the benefits received from various manufacturing industries. In the literature, it clearly showed that the case studies have been performed in the various manufacturing organizations, in seven different regions, such as USA, India, UK, China, Taiwan, New Zealand, and Malaysia. The significant benefit observed in the literature during LSS implementation is shown in Table 8.1.

8.2.1 Research Gap

While the implementation of lean six sigma approaches in manufacturing organization, it provided extensive benefits and helps to improve the quality and performance of the organization. The various literatures are evident that the various benefits have been observed by the manufacturing industry. Most of the author reported theoretically knowledge about LSS benefits, limitations, motivation factor, barriers, success factor; challenges from the best of our knowledge and study of literature, no separate study existed on the ranking of LSS benefits and their validation with the help of structured case study. As a result, these gaps have formulated the direction of this study.

Table 8.1 Benefits of Lean Six Sigma implementation

Sl. No.	LSS implemented industry/country	Reason of LSS implementation	Tools and techniques used	Identified benefits	References
1	Honeywell International Inc./(USA)	To improve productivity, quality and reduce cost	SPC, FMEA, C&E analysis, process mapping, 5S	Reduction in manufacturing cost by 50%	[1]
2	Proprietary military products/	To reduce cost of production and cycle time	DOE, C&E, SPC, SIPOC, brain storming	50% reduction in overall cost	[2]
3	Automobile Component mfg./(India)	To reduce the defects occurring in product	CVSM, VOC, TPM, Pareto chart, DOE, control chart	Significant improvement in key metrics	[3]
4	Tire production company/(India)	To reduce defect occurring in production	Root cause analysis, VSM, 5S, C&E analysis	Reduction in overall defects by 15%	[4]
5	Small engineering company/(UK)	To examine the validity of the new integrated LSS approach	VSM, 5S, DOE, TPM, SPC, QFD	Increase OEE and production performance	[5]
6	PCB manufacture/(China)	To change the manufacturing process	ANOVA, 5S, FMEA, TPM, C&E, process map	Increase the production rate	[6]
7	Touch Panel Mfg./(Taiwan)	To improve the quality of the touch panel	SIPOC, ANOVA, VOC, C&E, SPC, DOE, CVSM	32.4% Reduction in defects	[7]
8	Large valve manufacturing/(USA)	To reduce cost, the cycle time of the process and improve the overall quality of product	5S, Kaizen, value stream mapping, root cause analysis, brainstorming	The average lead time was reduced from 180 to 40 days	[8]
9	Printing sample board manufacturing company/(USA)	To meet the demand of industry and increase customer satisfaction rate	SOP, Pareto chart, check sheet, E-Kanban system	Customer demand has been met successfully	[9]
10	Automotive valve industry/(India)	To reduce the defects and FTR	SIPOC, VOC, 5S, VSM, DOE, C&E	Increase the FTR by 99.8%	[10]

(continued)

Table 8.1 (continued)

Sl. No.	LSS implemented industry/country	Reason of LSS implementation	Tools and techniques used	Identified benefits	References
11	Industrial cleaning equipment manufacturing/(USA)	To reduce overall cost, eliminate waste, and increase capacity	SIPOC chart, VSM, Pareto chart, CTQ analysis, FMEA, root cause analysis	Reduction in cost $660,000 per year, 50% reduction in the work cell	[11]
12	Compressor airfoil factory/(USA)	To enhance the quality of the product and improve the efficiency of the process	Failure mode and effect analysis, cause and effect analysis	94% of defects has been reduced, increase sigma value 0.86–3.21	[12]
13	Armaments product/(USA)	To reduce overall cost and cycle time of product	TPM, 5S, VSM, XY metrics, C&E analysis, SPC, ANOVA, DOE	Improvement such as 91% in quality, 70% in cost, 67% in delivery, 84% in risk	[13]
14	Aircraft manufacturing company/(USA)	To improve the position in the market, to increase the company bottom-line result	Kanban, cause and effect analysis, Jaidoka	The observed increase in sales from 30 to 205 m/year	[14]
15	Rotary switches industry/(India)	To reduce rework cost and defects	VSM, 5S, Kanban, DOE, Poka-yoke	Reduction in key metrics	[15]
16	The home furnishing industry/(USA)	To improve the process performance and product quality	SIPOC, SMED, ANOVA, VSM, Pareto chart	Improved performance and production capacity	[16]
17	Automotive Ind./(Malaysia)	To reduce the production cost	5S, SPC, VSM, brainstorming	Significantly reduce cost	[17]
18	Gas and Engineering industry/(USA)	To eliminate non-value adding activities and defects	CVSM, 5S, Poka-yoke, Spaghetti diagram	Increase productivity by 18–48%	[18]

(continued)

Table 8.1 (continued)

Sl. No.	LSS implemented industry/country	Reason of LSS implementation	Tools and techniques used	Identified benefits	References
19	Valve manufacturing organization/(India)	To reduce the defects occurring in the final product and improve the bottom-line	VSM, Pareto chart, C&E, FMEA, Kanban, Kaizen, Work cell, SMED	Reduction in overall defects and improve performance	[19]

8.3 Research Methodology

In this paper, authors used both qualitative and quantitative research methodology approaches to gather the data related to the implementation impacts of the lean six sigma approach in various selected manufacturing industries situated in India. The methodology consisted of two parts: the first part includes identification, selection, and ranking of LSS attributes and next part includes validation of ranked benefits. The methodology adopted in this study is clearly shown in Fig. 8.1.

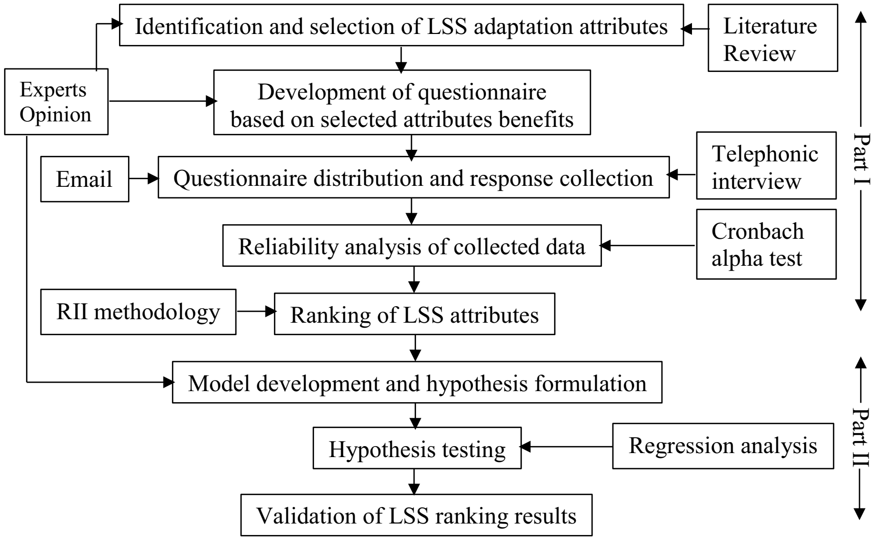

Fig. 8.1 Detailed research methodology

8.3.1 Relative Importance Index (RII)

The relative importance index technique is generally used to determine the rank of clusters. The RII has statistically ranked the clusters based on the responses data collected on a predefined scale from the various respondents. The 1–5-binary digit scale is mostly used to gather the response to analyze the data. The rank is obtained in this methodology using Eq. (8.1). This equation 'w' represents the weight given by the respondent for each attribute based on 1–5-Likert scale. The n_1 represents the minimum rating provided by the respondent, and n_5 represents the higher rating provided by the respondent on a given scale. The 'A' represents the highest weight (5 for this case), and 'N' shows the total number of response. The valid response data has been summarized in the Excel sheet and calculated using Eq. (8.1) [20–22].

$$\text{RRI} = \frac{\sum w}{AN} = \frac{5_{n5} + 4_{n4} + 3_{n3} + 2_{n2} + 1_{n1}}{5N} \tag{8.1}$$

8.3.2 Regression Analysis (RA)

Regression analysis (RA) is a powerful statistical methodology which allows for examining the relationship between two or more factors of interest. The different types are regression analysis such as simple, multiple, and logistics regression analysis that are existing in nature, and it used based on the nature of the problem. The regression analysis is generally used to identify the impact of an independent factor on the dependent factor. However, the identification of impact between both factors is performed using hypothesis formation and testing. Based on the identified standardized beta value and their significance obtained by the regression analysis, the hypothesis can be accepted or rejected. The standardized beta value also compares the impact strength of each independent factor on the dependent factor [23].

Part I: Identification, Selection, and Ranking

8.4 Case Study and Data Analysis

The various subsections describe the details about the case study and analysis of the data.

8.4.1 Problem Identification and Case Organization Description

The case organizations are suffering major problems related to defect occurs in the finished product. Thus, management of case organizations is struggling to adopt continuous improvement methodology such as LSS in their organizations. The three different manufacturing organizations such as a valve, cloth, and brake shoe manufacturing organization are considered to perform the study situated within different regions of India. The selection of case organization was based on getting permission to perform the study. The main aim of this study is to identify the benefits of LSS implementation in a manufacturing organization and further provide suggestions for the implementation in case organizations. In this context, the study identifies the main key benefits of LSS adaptation and gathered the responses from various LSS implemented manufacturing organizations located in India for prioritizing the possible key benefits after LSS implementation.

8.4.2 Identification and Selection of LSS Attributes

The various LSS benefits were identified through the literature review, and the keywords used to search are lean six sigma benefits, lean six sigma attributes, lean six sigma framework, lean six sigma from a different database such as Google Scholar and Scopus site. There are total of 10 benefits selected through expert's opinion in this study. The experts are having more than 10 years of experience in the concerned field. The selected LSS benefits are shown in Table 8.2.

Table 8.2 Selected LSS benefits

S. No.	LSS implementation benefits	References
1	Reduce overall defects in product	[1, 2, 9]
2	Reduction in inventory	[2–4, 11]
3	Reduce cycle time of product	[2, 3, 5, 12]
4	Reduction in machine breakdown time	[2, 6, 13]
5	Improvements in key performance metrics	[1, 2, 4, 6, 14]
6	Increase production capacity	[7, 12, 15, 16]
7	Improve product quality	[6–8, 15]
8	Reduction in overall production cost	[2, 4, 7, 16]
9	Increase customer satisfaction	[8, 9, 17]
10	Increase financial savings and profits	[7, 9, 10, 19]

8.4.3 Development and Distribution of the Questionnaire

The structured questionnaire was developed on the basis of ten selected LSS benefits with the help of experts. The questionnaire consisted four major parts: the first part includes general questions related to basic information about respondents; the second part includes basic information about the organization; the third part includes questionnaire itself, and the last part of the questionnaire consisted of suggestions and feedback. The questionnaire was distributed through email and direct meeting with industry managers, staffs, experts, suppliers, customers, and consultants of concerned manufacturing organization to analyze the impact of adaptation of the lean six sigma approach. The questionnaire has been mailed to respondents having at least 5 years' working experience in the selected organizations. The method for distribution was chosen based on the suitability of authors. The respondents were instructed to provide their responses based on the questions on the defined value of (1–5) Likert scale. The total 52 manufacturing organizations selected from the list of manufacturing organization found on Google. The selected organization consisted of three types of manufacturing organization situated in India. The all selected manufacturing organization is already implemented LSS approach either in whole or in a specific assembly line. From each manufacturing organization, six questionnaires were distributed and response collected from them. One organization with different stakeholder concepts was chosen to eliminate the biasedness of the data. The detailed survey is shown in Table 8.3.

8.4.4 Reliability Analysis

The questionnaire is shared with 312 different stakeholders of the selected manufacturing organizations and received total of 188 valid responses with 60.25% response rate. The details of the responses with the respondent profile and survey details are clearly shown in Fig. 8.2. The data reliability checks with the help of Cronbach's alpha test. The reliability analysis was performed using 'IBM SPSS Statistics 20' software. The consistency of the collected data was checked and found Cronbach's alpha value 0.795 that is good for the study.

8.4.5 Ranking of LSS Attributes

The collected data were analyzed using the relative importance index technique (RII). The RII is used in this study to rank the impacting factors. Equation (8.1) is used to calculate the RRI percent. The calculated RRI percentage of LSS attributes with ranking is shown in Table 8.4.

Table 8.3 Survey details

S. No.	Nature	Category	Questionnaire distributed		Response received		Total valid response	
			Email	Direct meeting	Email	Direct meeting	Email	Direct meeting
1	Organization type	Valve manufacturing	60	18	42	18	34	18
		Cloth manufacturing	114	24	89	24	61	24
		Brake shoe manufacturing	84	12	51	12	39	12
2	Organization size	Large	114	24	91	24	63	24
		Medium	84	12	57	12	39	12
		Small	60	18	51	18	32	18
3	Production type	Batch	228	36	103	36	95	36
		Mass	84	18	52	18	39	18
4	Respondent type	LSS experts	43	9	35	9	28	9
		Manager	43	9	33	9	25	9
		Head of staff	43	9	29	9	22	9
		Supplier	43	9	27	9	17	9
		Customer	43	9	33	9	18	9
		Consultant	43	9	36	9	24	9

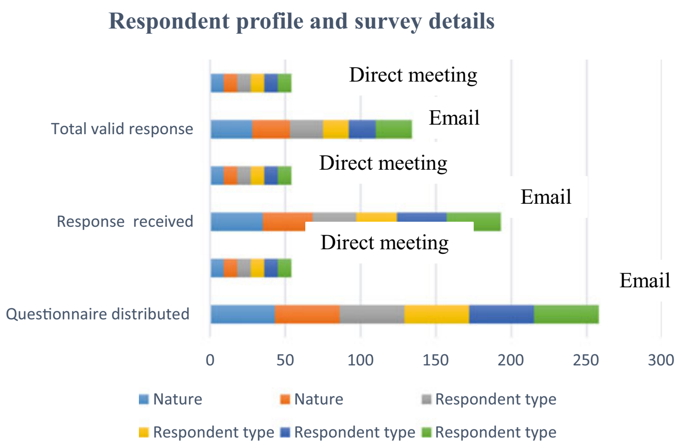

Fig. 8.2 Respondent profile and survey details

Table 8.4 Ranking of attributes based on relative importance index

Attribute name	No. of responses	Relative importance index percent (%)	Total score	Rank
Reduce overall defects in product	80	84.75	287	1
Reduction in inventory	80	83.50	252	2
Reduce cycle time of product	80	77.75	172	3
Reduction in machine breakdown time	80	75.50	272	4
Improvements in key performance metrics	80	70.75	273	5
Increase production capacity	80	66.75	241	6
Improve product quality	80	66.00	224	7
Reduction in overall production cost	80	64.75	214	8
Increase customer satisfaction	80	60.50	222	9
Increase financial savings and profits	80	60.25	274	10

Part II: Validation

8.4.6 Development of the Model

The research model for this study is developed with the help of area experts. For developing the model, ten LSS attributes are considered as independent factors and lean six sigma implementation benefits are considered as a dependent factor. The research model for this study is shown in Fig. 8.3.

8.4.7 Hypothesis Formulation

The hypothesis for this study is formulated with the help of an expert's opinion. The following hypothesis is formulated based on the developed model:

H1: The factor 'reduce overall defects in product' positively impacts on 'LSS implementation benefits.'

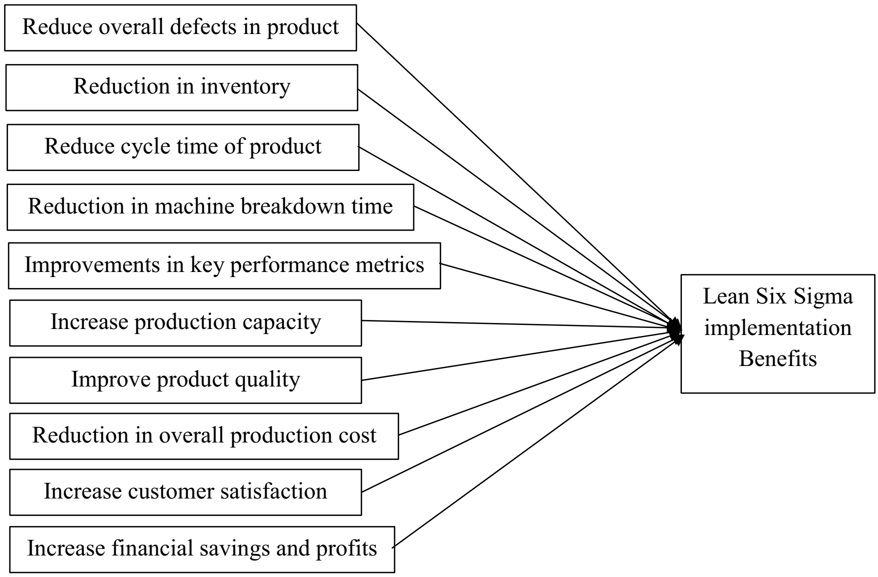

Fig. 8.3 Developed research model

H2: The factor 'reduction in inventory' positively impacts on 'LSS implementation benefits.'
H3: The factor 'reduce cycle time of product' positively impacts on 'LSS implementation benefits.'
H4: The factor 'reduction in machine breakdown time' positively impacts on 'LSS implementation benefits.'
H5: The factor 'improvement in key performance metrics' positively impacts on 'LSS implementation benefits.'
H6: The factor 'increase production capacity' positively impacts on 'LSS implementation benefits.'
H7: The factor 'improve product quality' positively impacts on 'LSS implementation benefits.'
H8: The factor 'reduction in overall production cost' positively impacts on 'LSS implementation benefits.'
H9: The factor 'increase customer satisfaction' positively impacts on 'LSS implementation benefits.'
H10: The factor 'increase financial savings and profits' positively impacts on 'LSS implementation benefits.'

8.4.8 Hypothesis Testing

Hypothesis testing is performed using regression analysis. The analysis is performed in 'IBM SPSS Statistics 20' software. The following steps are followed during the analysis of data to test the formulated hypothesis:

1. Open 'SPSS Statistics 20' software and copy or write all the 188 responses gathered from various respondents of LSS adopted industry on various independent as well as dependent factors.
2. Go to analyze (it could be seen in the upper side in software)—select regression analysis and select linear.
3. Place 'dependent factor response' independent section and select and place all 'independent factor response' independent section.
4. Click 'statistics' and tick on the following such as Estimates, Confidence intervals, Durbin–Watson, Casewise diagnosis, Model fit, Descriptions, Collinearly diagnosis than press continue.
5. Click 'plots' and place the 'ZPRED' responses (prediction values) in the *X* section and 'ZRESID' response in *Y* section than a parallel tick on the histogram and normal probability plot. After completion of the following task, click on continue.
6. Finally, press ok for the result.

The result obtained in this study is shown in Table 8.5.

Table 8.5 Regression analysis result

Independent factors	Dependent factors	
	Firm financial performance	
	Std. coeff. β	Sig.
Constant		0.463
Reduce overall defects in product	0.159	0.092**
Reduction in inventory	0.113	0.086**
Reduce cycle time of product	0.093	0.063**
Reduction in machine breakdown time	0.082	0.031*
Improvements in key performance metrics	0.063	0.048*
Increase production capacity	0.059	0.016*
Improve product quality	0.048	0.001*
Reduction in overall production cost	0.037	0.949**
Increase customer satisfaction	0.031	0.037*
Increase financial savings and profits	0.029	0.009*
R value	0.447	
R square value	0.997	
F value	2.078	

$P^{**} < 0.10$, $P^{*} < 0.05$, Std. Coeff. = Standardized coefficient, Significance = Sig.

The result of the analysis shows that the strength of the impacts of various LSS attributes on lean six sigma implementation benefits in any manufacturing organization. The impact strength can be observed with the obtained value of standardized coefficient beta value, and the hypothesis can be tested using the obtained significance value of all independent factors. In this study, hypothesis testing was done based on the obtained significance '*P*' value. The two '*P*' values considered in this study, and the difference between both is presented using star marks in Table 8.5.

8.5 Result and Discussion

Lean six sigma adaptation in manufacturing organizations provides certain benefits such as process performance improvement, financial enhancement, and increase rate of customer satisfaction. The successful adaptation of LSS also reduces machine downtime, product rejection rate, reduction in various inventories, changeover time, customer complaints. The case manufacturing organizations are suffering problem-related to defects occurring in the finished product and struggling to adopt a continuous quality improvement approach that can overcome such issues. After successful analysis, the gathered data from various stakeholders selected from different industries situated within India, and it found that the LSS attribute 'reduce overall defects in product' is prioritized as first LSS benefits, whereas 'increase financial savings and profits' prioritized as last key benefits using RII technique (the result are observed in Table 8.4). The prioritization of LSS attributes is shown in Fig. 8.4.

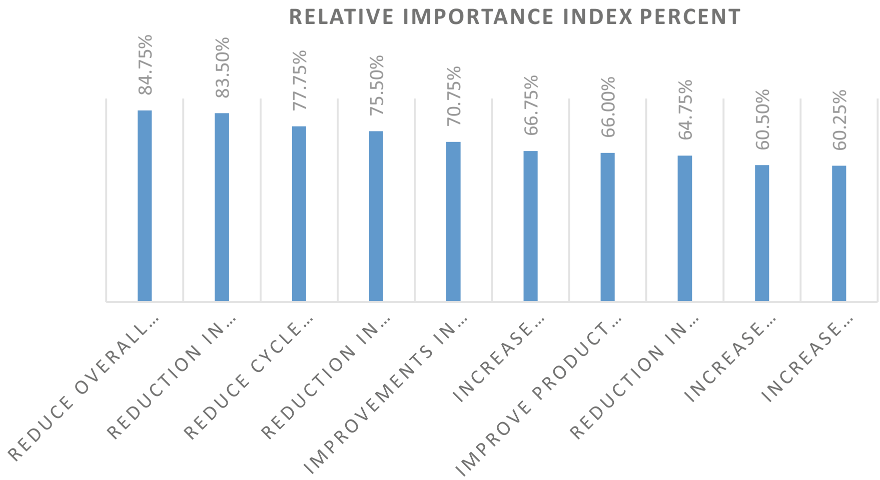

Fig. 8.4 Ranking of LSS attributes based on RII technique

To validate this result obtained from RII technique, the hypothesis testing is performed using regression analysis. Based on the result of regression analysis, the hypothesis is tested and found the following results:

H1 is accepted at a 0.10 level of significance.
H2 is accepted at a 0.10 level of significance.
H3 is accepted at a 0.10 level of significance.
H4 is accepted at 0.05 level of significance.
H5 is accepted at 0.05 level of significance.
H6 is accepted at 0.05 level of significance.
H7 is accepted at 0.05 level of significance.
H8 is accepted at a 0.10 level of significance.
H9 is accepted at 0.05 level of significance.
H10 is accepted at 0.05 level of significance.

The result of hypothesis testing indicated that all formulated hypotheses are having a positive impact on LSS implementation benefits which help for the further validation process. From the result of regression analysis, it is also observed the impact strength of LSS attributes on lean six sigma implementation on various benefits. It can be seen from Table 8.5, the standardized coefficient beta value indicated the impact strength. Based on the obtained beta value, the LSS attribute 'reduce overall defects in product' is prioritized as first LSS benefits, whereas 'increase financial savings and profits' prioritized as last key benefits. The other benefits are also obtained the same rank or priority as RII result. The prioritization of LSS attributes based on the result of regression analysis is shown in Fig. 8.5.

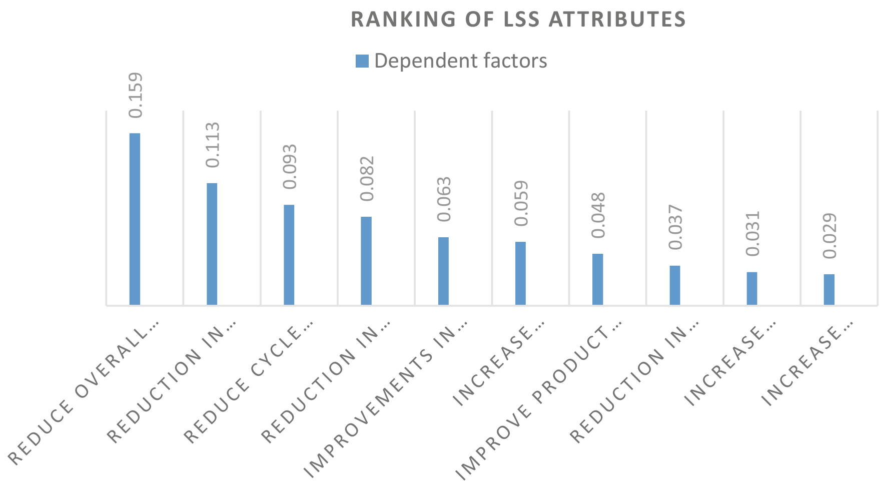

Fig. 8.5 Ranking of LSS attributes based on a regression analysis approach

8.5.1 Managerial Implications

Before implementing lean six sigma in any manufacturing organization, it needs to know about the main key benefits. The complete knowledge of LSS implementation benefits will help to recognize the purpose of implementation and compare it with the current problem for which they going to implement. If the purpose of implementation is matched, then management involvement assurance is needed for the further implementation process.

8.6 Conclusions

The findings of this study concluded that the adaptation of the lean six sigma approach providing an effective impact in manufacturing organizations to improve their bottom-line result. The result shows that significant improvement has been observed in LSS implemented industries based on the responses received from industry professionals. The study elaborated on the scope of lean six sigma implementation benefits in manufacturing organizations. The three most significant benefits have been observed such as reduce overall defects in the product, reduction in inventory, reduction in the cycle time of product having the relative importance index which are 84.75%, 83.50%, and 77.75%, respectively. The result of the present study indicated that the LSS principles are applicable to solve major issues or problems and provide an extra effort to manufacturing organizations to implement Lean Six Sigma in their process. The study observed that the adaptation of LSS strategy in case manufacturing organization provides extensive benefits such as the reduction in cycle time, lead time, workforce, inventory, defects and brings improvement in key metrics such as overall equipment effectiveness (OEE), first-time yield (FTY), and customer satisfaction. The success in adaptation of LSS will also bring the cultural changes in manufacturing organizations. Further, this study observed that the implementation of lean six sigma is starting only from the top management involvement of the organization and without it is not possible to implement in any aspects.

8.7 Limitations and Future Scope

This study has been performed by gathering the initial data related to LSS adaptation key benefits in 52 selected manufacturing organizations situated in India. The survey has been performed to identify and analyze the benefits of lean six sigma implementation of three manufacturing organizations. In the future, other manufacturing or service organization can also be considered. To validate this survey result, regression analysis approach is used, and in future the other methods such as graph theory (GT) and structural equation modeling (SEM) can be used with considering more organization. The author (s) is currently working on the development of a lean six sigma framework for manufacturing organization by continuously adopting the required lean six sigma tools and techniques.

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