Chapter

Integrated Lean-Green-Six Sigma Practices to Improve the Performance of the Manufacturing Industry

Lokpriya M. Gaikwad and Vivek K. Sunnapwar

Abstract

To survive in the global competitive market, the manufacturing organization must adopt changes in technologies and strategies into their processes on a continuous basis. So, nowadays, Lean, Green, and Six Sigma became business process strategies, which are employed in most of the organization to enhance their manufacturing performance. However, the significant information is that these strategies are implemented sequentially instead of simultaneously. The objective of this chapter is to propose an integrated Lean- Green-Six Sigma strategic framework for manufacturing industries that effectively implementing this approach will lead business processes to achieve operational, financial, social, and environmental growth. This will also guide the practitioner and academician those who are working on manufacturing strategies.

Keywords: Lean practices, Green practices, Six Sigma, integrated framework

1. Introduction

The expanded mindfulness about sustainability and requests for eco-friendly products has constrained the manufacturing firms to reevaluate their business activities [1]. Ventures are embracing the conventional strategies for manufacturing and petroleum products in the majority of the world [1]. The manufacturing enterprises in developed countries discharge multiple times carbon dioxide when contrasted with the developing nations [2]. The current arrangements on environmental change uncover that the normal surface temperature of the earth will increase to 3°C until the finish of this century [2]. This temperature increment is far away from the aggressive objective of the Paris Agreement that plans to confine it up to 2°C [3].

The hazard related to the atmosphere will increase in the offing because of expanded risk recurrence and increasingly powerless populace. Subsequently, for the government assistance of society and environmental assurance, enterprises must remember green innovations for their tasks. The presence of present-day businesses relies on their fitness to change with the external environment [4]. In this way, to stay practical in the market, manufacturing firms must create and actualize low carbon emanation advancements. Thus, the firms are spending huge money to devise sustainable techniques for creation and utilization [5].

Since the most recent couple of decades, numerous thoughts and approaches have been created such as Lean, Green, Six Sigma, and so forth [6, 7] to create the top quality items. Gaikwad and Sunnapwar [8] introduced critical achievement factors for executing incorporated LGSS rehearses in the manufacturing industry.

Yet, an individual methodology cannot address all the issues comprehensively identified with sustainability [9]. Along these lines, a coordinated methodology is required that lessens wastes and varieties and mitigates negative ecological effects [3]. Sreedharan and Raju [10] opined that GLS (Green Lean Six Sigma) is a comprehensive methodology that reduces ecological outflows through 3R's (reduce, reuse, and recycle).

LGSS comprises of three remarkable methodologies viz., Green, Lean, and Six Sigma that expand profitability elements through reduced emissions, wastes, and rework [11]. Lean promotes the efficient evacuation of wastes through excellence at all levels inside the firm [12, 13]. Green innovation diminishes the negative ecological effect of the item by making it all the more ecofriendly [14–16]. Six Sigma decreases varieties in the process that prompts diminished dismissal of products [17]. However, consolidated Green Lean Six Sigma is fit for creating an item that is not just of high caliber and ease yet in addition eco-friendly [18].

In the literature, there is significant proof of the combination and system of Lean and Green, Lean, and Six Sigma. In any case, the literature needs enough proof of the integration and structure of LGSS. There exist hardly any investigations related to the LGSS structure; however, the concerned associations confronted difficulties to execute the equivalent because of the conventional nature of the system [19]. In addition, in the literature, there exists no examination on the LGSS structure that can be applied independently of the size, type, and culture of the firm. For this, the current study gives reconciliation and system of LGSS for accomplishing greatness in profitability and environmental sustainability.

Lean Six Sigma is an approach that identifies the customer expectations, eliminates wastages, and reduces variability. It combines Six Sigma's problem-solving approach with statistical tools with a Lean effect on flow improvement [20]. Hence, the objective of industrial engineering to improve productivity through optimization techniques has been fulfilled.

Evidence suggests that LGSS approaches make a positive impact on social, economical, and environmental (i.e., sustainability) performance of the firm [21]. Therefore, industrial engineering practitioners make an effort toward the deployment of such types of approaches into their business. The industrial engineering field has also tremendous pressure to improve production efficiency concerning social and environmental responsibility, and also market dynamics have changed [15, 16]. Bergmiller and McCright [22] opined that the three elements of sustainability (economic, social, and environmental) should be mulled over by firms to keep their competitive edge. In this situation, the confront for firms is to meet all their stakeholders' requirements through achieving positive financial execution while finding the correct equilibrium among the triple bottom line of sustainability [23, 24].

2. Literature review

The historical backdrop of GLS followed back to the advancement of Lean way of the thinking. The Lean idea was contrived in Japan after the Universal War II to contend with the large scale manufacturing arrangement of the USA [5, 25]. The

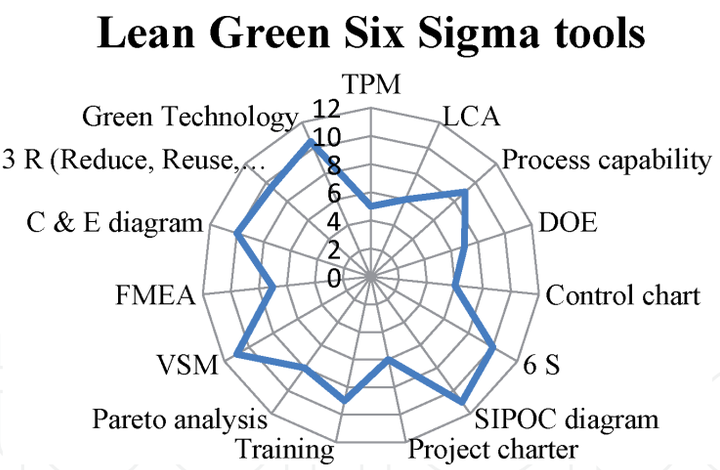

Figure 1.
Radar chart of LGSS tools.

cutting edge idea of Lean philosophy originated from the Toyota Production System (TPS), spearheaded by Japanese specialists Taiichi Ohno and Shigeo Shingo [3]. The Lean methodology diminishes wastes; it cannot lessen the unfriendly natural effects [26].

The execution of Green innovations can defeat this confinement of the Lean. Green innovation adds to Lean as it diminishes negative natural effects and other related wastes [27]. Green innovation decreases natural discharges; it cannot lessen the lean wastes [1]. Along these lines, there is a requirement for a consolidated Green Lean (GL) approach that limits Lean wastes as well as decreases the carbon footprint. There is a decent arrangement of similitude between the two strategies dependent on waste decrease procedures and management practices [22].

The majority of the investigations discover that there is an absence of metrics, top management backing, and standard method for execution of LGSS in the firm. The LGSS instruments can possibly discover the wastages, abandons, and undesirable exercises that lead to the advancement of resources [28]. As suggested by Kaswan and Rathi [4], LGSS tools are presented in **Figure 1** in the form of a radar chart.

3. Integration of lean green six sigma

The GLS has gotten due consideration as of late due to its capacity to improve efficiency, and profitability and alleviate environmental concerns [19]. LGSS framework proposes a hypothetical incorporation model of the LGSS dependent on the blend of hypothetical components. **Figure 2** delineates a coordinated LGSS framework. The reconciliation model's principle point is to depict the basic realities required for the manufacturing industry to improve sustainable execution. The proposed model speaks to the theoretical likenesses between the three methodologies. The empowering influences function as the key data sources that invigorate the incorporation of LGSS while the exhibitions in trade-off fill in as yield. The difficulties for the LGSS combination are the limitations that confine the hierarchical interests to improve the manageability elements. The apparatuses and related LGSS framework are considered as the supporting mechanism that bolsters the joining and execution of LGSS.

The goal is to maximize stakeholder value, by achieving customer satisfaction, process speed, cost, and quality through the tools and techniques [29]. This

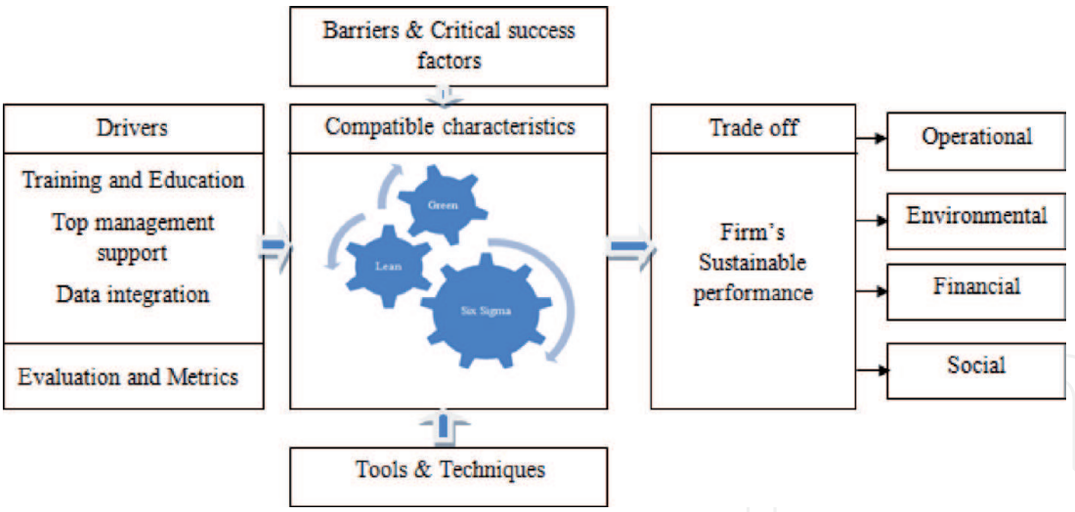

Figure 2.
Integrated framework of LGSS.

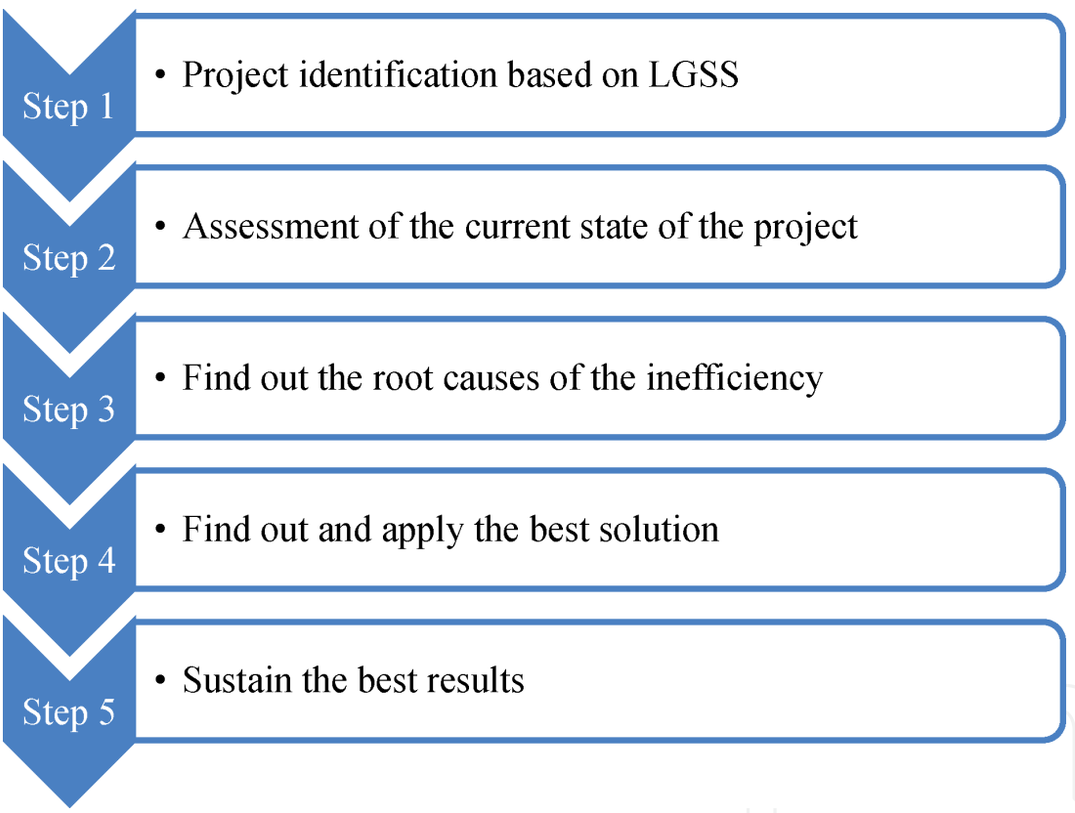

Figure 3.
Execution steps of LGSS framework.

initiative depends upon collaborative team effort to improve performance of the firm [30] to identify the need of the customers and to eliminate unwanted activities within the process [31]. The individual LGSS approach shares some similarities such as employee involvement, customer satisfaction, and continuous improvement [32]. Aqlan and Alfandi [33] opined that each of the practice has been carried out by many forms to improve their processes. Some researchers focus on Lean achievement in excellence through the reduction of waste and unwanted activities [34].

Following **Figure 3** depicts the Six Sigma DMAIC (Define-Measure-Analyze-Improve-Control)-based framework that can be adopted by all business firms. The proposed integrated framework has executed in the following five steps.

3.1 Execution steps of LGSS framework

3.1.1 Step 1: project identification based on LGSS

In this step, the project may be selected based on wastage, defect rate, environmental issues faced by the organization, social issues, financial issues, and voice of the customers. The selected project can be classified into different departments/sections of the company that is initiated the LGSS project. Gupta et al. [35] stated that most of the projects fail due to improper selection. Selection of the LGSS project depends upon sustainability need and global competitive pressure that force the firm to select the project. So, based on the customer demand, environmental concern, and socio-economic need, the final project is selected. After identification of a feasible project, a charter is prepared based on the scope of the project, schedule, and team members that involved in the project.

3.1.2 Step 2: assessment of the current state of the project

In this step, the current state of nature of the selected project has been estimated. Here, the performance of the selected project is compared with the indices of Lean, Green, and Six Sigma practices. Based on the collected data, the std. deviation, sigma level, and C_{pk} can be estimated using statistical tools. Estimations such as CO_2 emission, material consumption, Green energy coefficient are estimated using green energy technology tools like life cycle assessment. VSM is the best tool of Lean practices for evaluating the current degree of waste in the process. The blend of significant VSM and life cycle assessment lead to the evaluation of Lean-Green wastes that gives the source to assist improvement.

3.1.3 Step 3: find out the root causes of the inefficiency

In this progression, the underlying drivers of the wastefulness identified with wastages, emanation, and imperfection rate in the task have been distinguished. From the client and business perspective, the worth included and nonvalue included activities have been distinguished, and afterward, the procedure cycle effectiveness is resolved to contrast with world-class benchmarking value which decides how much improvement is required.

In the interim, the imperatives and bottlenecks are discovered in the chosen project and investigations identified with deformity rate, discharge rate, and varieties in the process are discovered. Advanced measurable quality tools, such as fishbone diagram, 5 Why, FMEA, and so on, are utilized to discover the main driver of the issue.

3.1.4 Step 4: find out and apply the best solution

Once the causes of inefficiency and wastages are find out, potential solutions are proposed and tested, and the best solution is applied to diminish the prominent reasons. All the sources of information such as customers, staff, stakeholders, project sponsors are used to determine the evaluation criteria. To evaluate the proposed solution against the criteria, tools such as pug matrix, DOE (Design of experiment), LCA, etc. are used. The estimation of time-saving, improved quality, and other quality measures is also made with enhanced VSM. After launching the best solution as a pilot solution, the task to be performed is documented, and pilot participants are trained in various aspects of the best solution. After that, the pilot solution is executed in a selected section or department of the company.

3.1.5 Step 5: sustain the best results

In this step, the results are sustained in the process or system if the considerable improvement is observed. The whole process is reevaluated using lifecycle assessment (LCA) and value stream mapping (VSM) techniques to judge the level of emissions and waste reduction. Also, various observations, control charts, and data collection techniques are used to reassess the sigma level, $C_{pk,}$ electricity, water, material consumption, etc. If the sustained results are not found, then an action plan is also initiated to select an appropriate solution. Through the execution of LGSS, the firm can gain improved sustainability, reputation, and global market through the delivery of eco-friendly products.

4. Results and discussion

LGSS is in the evolution phase and most of the firms oppose adopting such type of strategy due to the change in routine work method into their operation. However, the presented framework will help the organization for improving sustainable performance through overcoming the barriers and constraints which come in front of the execution.

After the integration of these strategies, one can correlate the different functionality of these modern techniques. It has found that top management support, a culture of the organization, and team work are the crucial success factors for the execution of such a program [4, 8]. In the same way, there are certain challenges to adopt these strategies because of improper guidance and roadmap to achieve set objectives of the firm [36]. There is a need to find out such types of obstacles during the execution of the improvement program within a given time frame to take a competitive advantage.

The LGSS tools and techniques overcome the barriers and at the same type advanced statistical tools help to find out the root cause of the problems and also to find out the solution for such type of problems. Currently, most of the organizations want to implement such types of manufacturing philosophies into their operation to enhance productivity, on-time delivery, improved quality, and reduced cost. In the LGSS framework, the Define-Measure-Analyze-Improve-Control (DMAIC) approach helps to overcome the barriers of the Lean-Green approach to delivering the sustainable results.

5. Proposed plan for validation

"The limitation of this work is that the presented framework has not tested statistically; in the future, the research will be based on an empirical study to be carried out in different industrial sectors." To validate the proposed plan, an empirical study taking a survey of manufacturing industries in which those practices are going on into their operation has need to be taken and then it should be statistically validated using SPSS-AMOS software.

In execution steps as shown in **Figure 3**, problem identification should be based on LGSS practices. Meanwhile, every problem that faces in the industry must be identified and solved by LGSS tools and techniques. Moving toward step 2, there should be an assessment of the current state of the problem to know the issues in the process. After that, the main drivers of the issues are associated with the inefficiency. Hence, the root causes using the fishbone diagram, 5 Why, DOE, etc. should be found out to deliver productivity to the system. After finding the root

cause of the problem, the best solution for implementation into practices should be found out. However, the best solution for the implementation should be sustained for continuous improvement. Everyone within the organization should be capable of finding solutions for the problems and sustaining the best solution into practice.

6. Conclusion

The LGSS approach reduces the negative environmental effect and improves operational, social, and financial performance. The integrated LGSS framework presented is based on theoretical elements such as tools and techniques, barriers, and enablers. Top management support and teamwork have a significant effect on execution of LGSS. The proposed framework provides a way of starting from project identification to finding a solution to the problem of implementation in a system/process. The stepwise framework of LGSS provides help to the operation manager to execute this sustainable approach irrespective of the size, culture, and type of industry. Providing this integrated approach, definitely, the organization can enhance its operational productivity keeping in mind socio-economic needs and global competitive pressure that force the organization to implement such type of approach.

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Conflict of interest

I confirm there is no "conflict of interest."

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References

[1] Siegel R, Antony J, Garza-Reyes JA, Cherrafi A, Lameijer B. Integrated green lean approach and sustainability for SMEs: From a literature review to a conceptual framework. Journal of Cleaner Production. 2019;**240**:118205

[2] Intergovernmental Panel on Climate Change. Global warming of 1.5° C: An IPCC special report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways. In: The Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Incheon, Republic of Korea: Intergovernmental Panel on Climate Change; 2018

[3] Kaswan MS, Rathi R. Analysis and modeling the enablers of green lean six sigma implementation using interpretive structural modeling. Journal of Cleaner Production. 2019;**231**:1182-1191

[4] Kaswan MS, Rathi R. Green lean six sigma for sustainable development: Integration and framework. Environmental impact assessment review. 2020;**83**:106396

[5] Duarte S, Cruz-Machado V. Green and lean supply-chain transformation: A roadmap. Production Planning and Control. 2019:1-13

[6] Bhat S, Gijo EV, Jnanesh NA. Application of lean six sigma methodology in the registration process of a hospital. International Journal of Productivity and Performance Management. 2014;**63**(5):613-643

[7] Garza-Reyes JA, Yu M, Kumar V, Upadhyay A. Total quality environmental management: Adoption status in the Chinese manufacturing sector. TQM Journal. 2018;**30**(1):2-19

[8] Gaikwad LM, Sunnapwar V. Critical success factors for implementing integrated lean green six sigma strategies: A framework. Journal of Industrial Engineering and its Applications. 2020a;**5**(1):25-40

[9] Pandey H, Garg D, Luthra S. Identification and ranking of enablers of green lean six sigma implementation using AHP. International Journal of Production Quality Management. 2018;**23**(2):187-217

[10] Sreedharan VR, Raju R. A systematic literature review of lean six sigma in different industries. International journal of Lean Six Sigma. 2016;**7**(4):430-466

[11] Kumar S, Luthra S, Govindan K, Kumar N, Haleem A. Barriers in green lean six sigma product development process: An ISM approach. Production Planning and Control. 2016;**27**(7-8):604-620

[12] Panwar A, Jain R, Rathore APS, Nepal B, Lyons AC. The impact of lean practices on operational performance–an empirical investigation of Indian process industries. Production Planning and Control. 2018;**29**(2):158-169

[13] Zhu Q, Johnson S, Sarkis J. Lean six sigma and environmental sustainability: A hospital perspective. Supply Chain Forum: An International Journal. 2018;**19**(1):25-41

[14] Deif AM. A system model for green manufacturing. Journal of Cleaner Production. 2011;**19**(14):1553-1559

[15] Garza-Reyes JA. Lean and green—A systematic review of the state of the art literature. Journal of Cleaner Production. 2015;**102**:18-29

[16] Garza-Reyes JA. Green lean and the need for six sigma. International Journal of Lean Six Sigma. 2015;**6**(3):226-248

[17] Kumaravadivel A, Natarajan U. Application of six-sigma DMAIC methodology to sand-casting process with response surface methodology. International Journal of Advanced Manufacturing Technology. 2013;**69**(5-8):1403-1420

[18] Hussain K, He Z, Ahmad N, Iqbal M. Green, lean, six sigma barriers at a glance: A case from the construction sector of Pakistan. Building and Environment. 2019;**106225**

[19] Sony M, Naik S. Green lean six sigma implementation framework: A case of reducing graphite and dust pollution. International Journal of Sustainable Engineering. 2019;**1-10**

[20] Message Costa LB, Filho MG, Fredendall LD, Devós Ganga GM. Lean six sigma in the food industry: Construct development and measurement validation. International Journal of Production Economics. 2020;**231**. DOI: 10.1016/j.ijpe.2020.107843

[21] Cherrafi A, Elfezazi S, Govindan K, Garza-Reyes JA, Benhida K, Mokhlis A. A framework for the integration of green and lean six sigma for superior sustainability performance. International Journal of Production Research. 2016;**55**. DOI: 10.1080/00207543.2016.1266406

[22] Bergmiller GG, McCright PR. Parallel models for lean and green operations. In: Proceedings of the 2009 Industrial Engineering Research Conference. Florida: The University of South Florida and Zero Waste Operations Research and Consulting; 2009. pp. 1138-1143

[23] Alves JRX, Alves JM. Production management model integrating the principles of lean manufacturing and sustainability supported by the cultural transformation of a company. International Journal of Production Research. 2015;**51**(11):1-14

[24] McCarty T, Jordan M, Probst D. Six Sigma for Sustainability–How Organizations Design and Deploy Winning Environmental Programs. New York: McGraw–Hill; 2011

[25] Bhamu J, Singh Sangwan K. Lean manufacturing: Literature review and research issues. International Journal of Operations & Production Management. 2014;**34**(7):876-940

[26] Aggogeri F. Lean thinking to change healthcare organizations: A case study to reduce waste and redesign services. European Journal of Cross-Cultural Competence and Management. 2014;**3**(3-4):196-211

[27] Dües CM, Tan KH, Lim M. Green as the new lean: How to use lean practices as a catalyst to greening your supply chain. J. Cleaner Production. 2013;**40**:93-100

[28] Gaikwad LM, Sunnapwar V. An integrated approach for lean, green and six sigma strategies: A systematic literature review and future directions for developing a specific framework. TQM Journal. 2020b;**32**(2):201-222. DOI: 10.1108/TQM-08-2018-0114

[29] Laureani A, Antony J. Standards for lean six sigma certification. International Journal of Productivity and Performance Management. 2011;**61**:110-120. DOI: 10.1108/17410401211188560

[30] Rajak AK, Niraj M, Kumar S. In pursuit of lean six sigma: A systematic review. International Journal of Applied Engineering Research. 2016;**11**:547-556

[31] Yadav G, Desai TN. Lean six sigma: A categorized review of the literature. International Journal of Lean Six Sigma. 2016;**7**:2-24. DOI: 10.1108/IJLSS-05-2015-0015

[32] Laureani A, Antony J. Leadership characteristics for lean six sigma. Total

Quality Management. 2017;**28**:405-426. DOI: 10.1108/17410401211188560

[33] Aqlan F, Al-fandi L. Prioritizing process improvement initiatives in manufacturing environments. International Journal of Production Economics. 2018;**196**:261-268

[34] Fullerton RR, Kennedy FA, Widener SK, Huntsman JM. Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices. Journal of Operations Management. 2014;**32**:414-428

[35] Gupta SK, Gunasekaran A, Antony J, Gupta S, Bag S, Roubaud D. Systematic literature review of project failures: Current trends and scope for future research. Computers and Industrial Engineering. 2019;**127**:274-285

[36] Gamal Aboelmaged M. Reconstructing six sigma barriers in manufacturing and service organizations: The effects of organizational parameters. International Journal of Quality & Reliability Management. 2011;**28**(5):519-541