XVII International Scientific Conference on Industrial Systems (IS'17)
Novi Sad, Serbia, October 4. – 6. 2017.
University of Novi Sad, Faculty of Technical Sciences,
Department for Industrial Engineering and Management
Available online at http://www.iim.ftn.uns.ac.rs/is17

The impact of lean tools on cost-based efficiency: Evidence from the transitional economy

Dragan Blažić, M.Sc.
(PhD Student, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, dragan92blazic@gmail.com)

Milan Delić, Ph.D.
(Assistant Professor, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, delic@uns.ac.rs)

Nela Cvetković, M.Sc.
(Teaching Assistant, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, nelacvetkovic@uns.ac.rs)

Vijoleta Vrhovac, M.Sc.
(Teaching Assistant, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, violeta.vrhovac@uns.ac.rs)

Tamara Peković, B.Sc.
(Teaching Assistant, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, pekovictamara@gmail.com)

Abstract

The objective of this study is to determine the relationship between the implementation of lean tools and cost-based efficiency organizational performance, in transitional economy conditions. The study was carried out in Serbia, using a sample of 217 organizations, from various industry sectors. For the purpose of this study questionnaire was used as a research instrument. Multiple regression analysis was used to examine the relationships between the aforementioned dimensions. It has been shown that Kanban, SQC, TPM, 5S, CM and VSM are the only tools which produce statistically significant results on cost-based efficiency performance. The results of this study point to the conclusion that the effects of lean tools implementation in transitional conditions are arguable. The discrepancies between this study and the results from developed economies yield potential improvement areas on how organizations in transitional economies should manage their organizations. Consequently, the implementation of lean tools might be a part of a good strategic choice for transitional organizations to overcome troublesome transitional times.

Key words: *Lean tools and practices, cost efficiency, organizational performance*

1. INTRODUCTION

Nowadays firms are operating in a complex environment with continuous changes, challenging them to constantly strive for the new tools and techniques requisite for increase of production performance, quality improvement, customer satisfaction and creation of a competitive advantage [1]. What seems as promising method for achieving these main organizational goals [2] is application of lean manufacturing principles and techniques (Prieto-Avalos et al. 2014).

The lean production practices enable companies to gain increasingly high level of efficiency and productivity, with improved speed of delivery, minimum stock levels and optimum quality. Furthermore, Lean approach makes possible for firms to achieve competitiveness at the lowest cost by enabling them to adapt their offering to actual demand and use the minimum amount of resources, consequently minimizing the cost [3].

Lean can be considered as a production strategy, which main purpose is helping to eliminate all operations with non-value added to the product and processes, reducing or eliminating all waste and looking for improvement process operations [4].

In this paper, we have examined the relationship of lean tools and principles and cost efficiency. In accordance with the literature, the included lean tools in this paper are: Kanban, Layout-continuous flow manufacturing, Visual management (VM), Statistical process control (SPC), Total Productivity Maintenance (TPM), 5S Housekeeping, Value Stream Mapping (VSM), Root cause analysis and elimination (RCA), Cellular manufacturing (CM), Standard work, Single-Minute Exchange of Dies (SMED) and One-piece flow. The effect of chosen dimensions on cost efficiency has been examined using multiple regression analysis. The findings reveal that dimensions: Kanban, SQC, TPM, 5S and VSM show effect on cost efficiency. The lack of relationship between other lean tools indicates the arguments on success of lean tools implementation in developing countries.

2. LITERATURE REVIEW

In his book "The Toyota Way", Liker (2004) defined Lean as a philosophy of manufacturing focused on delivering the highest product on time and at the lowest cost. Many authors identified that running operations at the lower cost is one of the priorities for organizations that seek to survive in the competitive environment. These tendencies are clarified by Slack (1991) who made a classification of competitive priorities including cost efficiency, where he defined a goal to offer products at a lower cost that the competition, hence the tendencies to optimize operating expenses. Lean Six Sigma has been recognized as one of the most effective business improvement techniques offering a cost reduction mechanism among the rest (Jayaraman, Leam Kee, & Lin Soh, 2012). There is evidence in the literature that some organizations produce substantial cost savings through application of Lean Six Sigma (Thomas, Barton, & Chuke-Okafor, 2008).

On the other hand, it is important to understand that if Lean Six Sigma must not be seen as a means of quickly cutting costs, as it will limit the organizations to achieve the real benefits of Lean Six Sigma [5].

3. RESEARCH MODEL- DIMENSIONS AND HYPOTHESES

Lean manufacturing implementation is associated with productivity increase, quality improvement, reduction of lead time [6], (Prieto-Avalos et al. 2014) while the main goal of this approach is cost reduction by decreasing non-value activities [7].

Therefore, in this paper, we have examined the influence of 12 Lean tools on cost effectiveness. Cost effectiveness implies achieving organizational results and performing operations at lower cost. The measures building this dependent variable are: reduction of total transport cost, inventory cost, decrease of costs cause by complaints and poor quality and finally profit increase.

Following, brief explanations of each independent dimension in the model are given and hypotheses are presented.

Kanban: Kanban is seen as efficient system for the improvement of the process flow between suppliers, manufacturing warehouse and the assembly line, providing more control at the operational level and reducing the risk of material shortage. Reduction of the inventory of overproduction with application of Kanban system improves the cash flow [8]. Implementation of Kanban supports decrease of WIP inventory and reduction of non-value added time. On this basis, the following assumption was set:

H1: Kanban has a positive effect on cost efficiency.

Layout - Continuous flow manufacturing: The results from different studies show that continuous flow is crucial for lean manufacturing implementation (Zahraee 2016b). Continuous flow manufacturing should provide an effective material flow path with no backtracking, congestion, undesirable intersections with other paths, and bypassing [9] where the efficiency of a layout is typically measured in terms of material handling (transportation) cost [10]. The aforementioned statements imply following assumptions:

H2: Layout - continuous flow manufacturing has a positive effect on cost efficiency.

Visual management (VM): In response to complex and heavily textual work instructions, which rarely avail the overall operational performance [11], adoption of visual management (VM) has been gaining on importance. VM can be explained as economically affordable and effective sensory information tools integrated into the workplace to increase the information availability and transparency [11], (Tezel et al. 2016). VM has demonstrated practical implications such as reduction in process and motion wastes and delivery delays [12], [13] and better utilization of resources. In accordance to the previously said, the following assumption was set:

H3: VM has a positive effect on cost efficiency.

Statistical process control (SPC): Unstable and uncontrollable process results in production of nonconforming product, which affect the overall production performance. To overcome this, the implementation of SPC is being proposed, in order to achieve continuous improvement of the production capabilities [14]. The purpose of SPC implementation is to improve the product quality, improve productivity, reduce wastes, reduce defects and improve customer values [15] and to identify the significant defect and reduce the process variations to consistently produce more conforming products, consequently contributing to the cost improved manufacturing process [16]. This implies:

H4: SPC has a positive effect on cost efficiency.

Total Productivity Maintenance (TPM): The TPM technique helps the companies to fare well in terms of setup time and cost reduction [16]. TPM implies that all machines and facilities are maintained in controlled working conditions, in order to prevent from failures and delays in manufacturing process. Therewith, the aim is to maximize overall equipment effectiveness (OEE), implying that facilities are at maximum utilization level, without malfunctions and scrapped products or semi-final products, eliminating the possibilities for additional costs. Accordingly, the assumption is:

H5: TPM has a positive effect on cost efficiency.

5S Housekeeping: The purpose of the 5S application is to discard unnecessary tools and designate different types of tools for easy access, enhancing productivity of the shop [16]. Moreover, workplace standardization increases space utilization, reduces redundant workers movements and material, improves productivity and safety and helps decrease of inventory, resulting in cost savings. This implies:

H6: 5S has a positive effect on cost efficiency.

Value Stream Mapping (VSM): Studies show that application of VSM facilitates identification of different improvement possibilities necessary for accomplishment of results, such as WIP reduction, reduction of final products inventory and decrease of processing time [16]. VSM is considered cornerstone of the lean strategy on the most important measures of operational performance, i.e. speed, quality, flexibility and cost [16]. On this basis, the following assumption was set:

H7: VSM has a positive effect on cost efficiency.

Root cause analysis and elimination (RCA): Root cause analysis presents a problem solving method used to identify the root causes of problems, acting as a pro-active tool of continuous improvement [17]. To expose the root cause of variation that results in inadequate process outputs, Lean deploys data and statistical analysis. A case study in a manufacturing company [17] marked that reducing process variations results in a higher quality product and financial savings from reducing scrap, defects, labor costs, etc. Accordingly, we assume following:

H8: Root cause analysis and elimination has a positive effect on cost efficiency.

Cellular manufacturing (CM): CM implies that the entire process is systemized for a particular product or related products into a set or cell that includes all the necessary equipment, machines and operators (Zahraee 2016a). Among many techniques in lean manufacturing, cellular manufacturing is associated mainly with the inventory and the lead times [17]. Existing literature reveals that the main incentives for implementation of CM are minimization of the throughput time, improvement of the product quality, reduction of the WIP levels and stocks and thereby, decrease of cost. On this basis, the following assumption was set:

H9: CM has a positive effect on cost efficiency

Standard work: To ensure high overall performance and enhance human effectiveness in production processes, it is recommended to create work instructions for standard operation procedures, since they ensure that processes are consistent, timely and repeatable [17]. Also, standard operation procedure has been observed to play a key role in variability process reduction [18] and decrease of human error. Thus, the assumption is:

H10: Standard work has a positive effect on cost efficiency.

SMED - change-over times: The SMED technique represents lean tool intended to reduce waste in the production system and to standardize machine changeover times [18], [19]. Although, the main goal of SMED is to reduce machine changeover time, with the standardization of the changeover necessary resources are planned and quantified, enabling inclusion of certain improvements to reduce necessary resources (Lozano et al. 2016). Furthermore, since the benefits that can be obtained by applying SMED are mainly time savings, and time can be translated into money or use of that time for other tasks that will also provide profits [20]. We assume following:

H11: SMED has a positive effect on cost efficiency.

One-piece flow: One-piece flow is lean tools mostly used for reduction of inventory (Belekoukias et al. 2014). From an economic point of view, short throughput times, high schedule reliability, high utilization and low work in progress inventory are very important logistic objectives. As there is no possibility for manufacturing enterprises to reach the highest level in all four objectives, a logistic operating curve calculation offers the best compromise among them [21]. The following assumption was set:

H12: One-piece flow has a positive effect on cost efficiency.

4. RESEARCH METHOD AND RESULTS

4.1 *Measures and questionnaire development*

The questionnaire was developed in accordance with Saraph, et al. (1989). Thus, only measures with a theoretical backbone and empirical validation were included. Firstly, face validity checking by a group of university professors was performed, where needed minor corrections were made following their suggestions. Secondly, the pilot test was conducted with 15 companies from various industry sectors by production managers. Finally, the research instrument contained 12 measures of lean concepts and 5 items grouped into one dependent variable - cost efficiency. For acquiring respondents' subjective estimates, a five-point Likert scale was used. (Nunnally,1994)

4.2 *Distribution and data gathering*

Each organization found on the list provided by Statistical Office of the Republic of Serbia (www.stat.gov.rs) was contacted and an invitation letter was sent to their production managers. Total number of initially contacted organizations was 707, out of which 516 (72.98%) expressed a desire to take part in this research.

An electronic version of the questionnaire was distributed to each organization. To minimize the bias effect, only one reply per email address (i.e. organization) was accepted. Further activities were conducted following the Dillman's (2008) approach. The administration process was followed by a series of follow-up email reminders if needed. After a three-month period, out of 516, 217 (30.69%) respondents filled out the questionnaire.

4.3 *Reliability test*

Cronbach alpha for the Lean measurement scale satisfies the minimum criteria. (≥ 0.7; Nunnally, 1994).

Table 1: Constructs, correlation and constructs' descriptives

Construct	Kanban	Continuous Flow	Visual Management	SPC	TPM	5S	VSM	Poka Yoke	Autonomation Work Units	Standardization	SMED	One Piece Flow	Cost Efficiency
Mean	2.46	3.80	2.53	2.82	2.52	4.03	2.85	4.16	3.23	3.72	3.19	3.08	3.51
StDev	1.367	1.115	1.414	1.356	1.342	1.142	1.274	.983	1.337	1.189	1.359	1.378	.91693
1	1	.288**	.479**	.452**	.496**	157	.470**	.186	.174	.317**	.329**	.340**	.208**
2		1	.262**	.289**	.279**	.285**	.434**	.375**	.081	.435**	.245**	.332**	.307**
3			1	.717**	.639**	.190*	.507**	.156	.309**	.560**	.313**	.275**	3.74**
4				1	.708**	.284**	.546**	.317**	.268**	.527**	.264**	.316**	.322*
5					1	.339*	.597**	.326**	.296**	.514**	.348**	.358**	.467**
6						1	.392**	.558**	.044	.356**	.367**	.211*	.451**
7							1	.448**	.310**	.499**	.297**	.330**	.425**
8								1	.228*	.388**	.363**	.259**	.201*
9									1	.280**	.135	.229*	.101
10										1	.426**	.421**	.360**
11											1	.538**	.386**
12												1	.357**
13													1

*** Statistically significant at the 0.01 level (2-tailed)*

** Statistically significant at the 0.05 level (2-tailed)*

4.4 *Regression analysis and results*

In order to examine the impact of Lean tools on dependent variable (cost-efficiency) multiple linear regression is performed, using SPSS software (V2.3).

Delivered R^2 (0.461) implies adequate relationship between Lean tool (Kanban, statistical tools, TPM, 5S, VSM and CM) and cost-efficiency, where Lean constructs depicts 46% of variation in cost-efficiency performance (Figure 1).

Focus area of this research model is impact of Lean tools on cost-efficiency. Correlation coefficients between these dimensions should indicate the level of Lean tools influence on cost reduction, which is a desired outcome. The research model is tested in order to demonstrate the effect of Lean tools on organizational performance, i.e. cost efficiency, which resulted in $R^2 = 0.461$. Thus, the adequacy of research model is confirmed. The influence of each stated Lean tool on cost-efficiency is examined in the following paragraphs, examining the value of their significance path coefficients.

Analysis shows that 5S concept, among other model constructs, has the greatest positive influence on cost efficiency; it obtains significance path value with 0.006 (Figure 1). Further results demonstrate that other constructs with positive effect on the dependent variable are: Kanban, SPC, TPM, 5S, VSM and CM, with significance path coefficients 0.040, 0.032, 0.017, 0.006, 0.019 and 0.043, respectively. Considering this, it can be said that hypotheses H1, H4, H5, H6, H7 and H9 are not being rejected.

On the other hand, Lean tools showing no significant impact (significance path coefficient >0.05) on cost-efficiency are: continuous flow, visual management, Poka Yoke, autonomous work units (cell manufacturing), standard work, SMED and one-piece flow. According to this, assumptions H2, H3, H8, H10, H11 and H12 are being rejected.

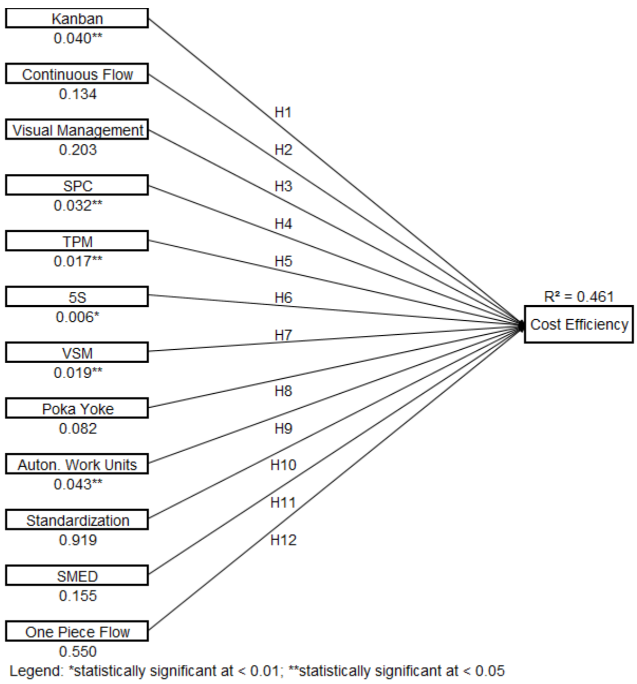

Figure 1. Research model

5. DISCUSSION

Using data collection from 217 firms in Serbia and multiple regression model, the research examined the extent to which the application of Lean tools in firms impacts organizational cost efficiency.

The results obtained in this paper partially support the findings of certain previous studies [8], [22], [23], [24], [25], [26], [27], [28], [29]. These results confirm the statistically significant influence of the whole model on the variability of organizational cost efficiency as one of the most desired organizational performance improvement.

Nonetheless, observing the values of each dimension individually, it is clear that not all lean tools have statistically significant impact on cost efficiency. Continuous flow, VM, RCA, standardization, SMED and one-piece flow with weights > 0.05 (0.134, 0.203, 0.082, 0.919, 0.155, and 0.550, respectively) do not demonstrate influence on dependent variable in this study. However, these results do not have to strictly imply the general lack of influence of these Lean tools on improvement of cost-based efficiency of an organization. There are few possible explanations for this. Few studies have shown that effects of Lean tools on organizational performances might vary depending on the level of the adoption of the lean techniques [30]. In their study, authors [31] discuss that factors like timing, scale, and extent of lean implementation can regulate the benefits of lean.

In addition, not rarely the relationship between Lean and performance is influenced by “moderating” factors such as such as plant age, production characteristics, size of the plant, geographic location, organizational structure, etc. [32], implying that, regardless of establishing what lean is, it remains important to establish how best to become lean in varied contexts [31].

Overall, findings reveal that, although firms recognize the importance and benefits related to Lean tools, there are challenges considering the implementation and application of those tools in specific organizational environment in order to enhance organizational performances.

6. CONCLUSION

The subject of this paper is the impact of Lean tools on cost-based efficiency of organizations in Serbia as transitional country.

The study results confirm significant relationships between some Lean practices (Kanban, SPC, TPM, 5S, VSM and CM) and cost efficiency, while influence of continuous flow, VM, RCA, standardization, SMED and one-piece flow on dependent variable in this research is not demonstrated. The main assumption for this outcome is the existence of various “moderate” factors causing variations in effects of different Lean tools on organizational performances, such as plant age, production characteristics, size of the plant, geographic location and organizational structure. Furthermore, the important role in these relations has the level of the adoption of the lean techniques, implying the need for strategic planning of introduction of Lean in varied contexts.

Considering this, the implication for companies in Serbia is to observe their firm as a system of many interdependent elements which all have direct or indirect influence on success of Lean implementation and consequently, on its positive effect on performance improvement.

7. REFERENCES

[1] M.C. Prieto-avalos, Navarro-gonzález, C.R.Medina-león, and A. G. S.V., “Reduction Waste by Combining Lean Manufacturing and Six Sigma in an Electronics Industry,” *Res. J. Appl. Sci. Eng. Technol.*, vol. 8, no. 13, pp. 1558–1562, 2014.

[2] B. S. Kumar and S. S. Abuthakeer, “Implementation of Lean Tools and Techniques in an Automotive Industry,” *J. Appl. Sci.*, vol. 12, no. 10, pp. 1032–1037, Oct. 2012.

[3] L. Cuatrecasas Arbos, “Design of a rapid response and high efficiency service by lean production principles: Methodology and evaluation of variability of performance,” *Int. J. Prod. Econ.*, vol. 80, no. 2, pp. 169–183, 2002.

[4] P. P. B. Silva, “Algunas reflexiones para aplicar la manufactura esbelta en empresas colombianas,” *Sci. Tech.*, vol. 1, no. 38, Jun. 2008.

[5] J. P. Womack and D. T. Jones, *Lean solutions : how companies and customers can create value and wealth together*. Free Press, 2005.

[6] R. Marudhamuthu and M. Krishnaswamy, “THE DEVELOPMENT OF GREEN ENVIRONMENT THROUGH LEAN IMPLEMENTATION IN A GARMENT INDUSTRY,” vol. 6, no. 9, 2011.

[7] S. M. Zahraee, “A survey on Lean Manufacturing implementation in a selected manufacturing industry in Iran,” *Int. J. Lean Six Sigma*, vol. 7, no. 2, p. , 2016.

[8] M. Amin, M. Hashim, and A. Ismail, “Improvements of worksite control for pull system,” vol. 11, no. 12, pp. 7699–7705, 2016.

[9] D. Falcone, F. De Felice, A. Silvestri, and A. Petrillo, “A Multi – objective methodological approach for mapping material flows and optimizing layout,” in *Proceeding of The international Workshop on Innovation for Logistics (WIN-LOG) 2013*, 2013, pp. 1–9.

[10] A. Petrillo, F. De Felice, A. Silvestri, and D. Falcone, “Lay-out optimisation through an integrated approach based on material flow and operations mapping using a commercial software,” *Int. J. Serv. Oper. Manag.*, vol. 23, no. 1, p. 113, 2016.

[11] A. Tezel, L. Koskela, and P. Tzortzopoulos, “Visual management in production management: a literature synthesis,” *J. Manuf. Technol. Manag.*, vol. 27, no. 6, pp. 766–799, 2016.

[12] J. H. Ablanedo-Rosas, B. Alidaee, J. C. Moreno, and J. Urbina, “Quality improvement supported by the 5S, an empirical case study of Mexican organisations,” *Int. J. Prod. Res.*, vol. 48, no. 23, pp. 7063–7087, Dec. 2010.

[13] J. C. Chen, Y. Li, and B. D. Shady, “From value stream mapping toward a lean/sigma continuous improvement process: an industrial case study,” *Int. J. Prod. Res.*, vol. 48, no. 4, pp. 1069–1086, Feb. 2010.

[14] A. Azizi, “Evaluation Improvement of Production Productivity Performance using Statistical Process Control, Overall Equipment Efficiency, and Autonomous Maintenance,” *Procedia Manuf.*, vol. 2, no. February, pp. 186–190, 2015.

[15] M. . Soković, J. . Jovanović, Z. . Krivokapić, and A. . Vujović, “Basic quality tools in continuous improvement process,” *Stroj. Vestnik/Journal Mech. Eng.*, vol. 55, no. 5, pp. 1–9, 2009.

[16] B. S. Kumar and S. S. Abuthakeer, “Implementation of Lean Tools and Techniques in an Automotive Industry,” *J. Appl. Sci.*, vol. 12, no. 10, pp. 1032–1037, Oct. 2012.

[17] M. D. AL-Tahat and I. S. Jalham, “A structural equation model and a statistical investigation of lean-based quality and productivity improvement,” *J. Intell. Manuf.*, vol. 26, no. 3, pp. 571–583, 2015.

[18] C. Forza, “Work organization in lean production and traditional plants,” *Int. J. Oper. Prod. Manag.*, vol. 16, no. 2, pp. 42–62, Feb. 1996.

[19] J. Lozano, J. C. Saenz-Díez, E. Martínez, E. Jiménez, and J. Blanco, “Methodology to improve machine changeover performance on food industry based on SMED,” *Int. J. Adv. Manuf. Technol.*, pp. 1–12, 2016.

[20] M. N. Bin Che Ani and M. S. S. Bin Shafei, “The Effectiveness of the Single Minute Exchange of Die (SMED) Technique for the Productivity Improvement,” *Appl. Mech. Mater.*, vol. 465–466, pp. 1144–1148, Dec. 2013.

[21] P. Nyhuis and M. Vogel, “Adaptation of logistic operating curves to one-piece flow processes.”

[22] B. S. Kumar and S. S. Abuthakeer, “Implementation of Lean Tools and Techniques in an Automotive Industry,” *J. Appl. Sci.*, vol. 12, no. 10, pp. 1032–1037, Oct. 2012.

[23] A. Azizi, “Evaluation Improvement of Production Productivity Performance using Statistical Process Control, Overall Equipment Efficiency, and Autonomous Maintenance,” *Procedia Manuf.*, vol. 2, no. February, pp. 186–190, 2015.

[24] G. V. Prabhushankar, K. Kruthika, S. Pramanik, and R. S. Kadadevaramath, “Lean manufacturing system implementation in Indian automotive components manufacturing sector - an empirical study,” *Int. J. Bus. Syst. Res.*, vol. 9, no. 2, p. 179, 2015.

[25] S. S. Chakravorty and A. D. Shah, “Lean Six Sigma (LSS): an implementation experience,” *Eur. J. Ind. Eng.*, vol. 6, no. 1, p. 118, 2012.

[26] B. Singh, S. K. Garg, and S. K. Sharma, “Development of index for measuring leanness : study of an Indian auto component industry,” vol. 14, no. 2, pp. 46–53, 2010.

[27] I. Belekoukias, J. A. Garza-Reyes, and V. Kumar, “The impact of lean methods and tools on the operational performance of manufacturing organisations,” *Int. J. Prod. Res.*, vol. 7543, no. July 2014, pp. 1–21, 2014.

[28] S. M. Zahraee, “A survey on Lean Manufacturing implementation in a selected manufacturing industry in Iran Seyed Mojib Zahraee Article,” *Int. J. Lean Six Sigma*, vol. 7, no. 2, p. , 2016.

[29] V. Ratnayake, G. Lanarolle, C. Perera, and J. Marsh, “Cellular manufacturing model to reduce WIP fluctuation in garment manufacturing,” *Int. J. Six Sigma Compet. Advant.*, vol. 5, no. 4, pp. 340–358, 2009.

[30] K. Cua and R. McKone-Sweet, Kathleen; Schroeder, “Improving Performance through an Integrated Manufacturing Program,” *Qual. Manag. J.*, pp. 45–60, 2006.

[31] R. Shah and P. T. Ward, “Defining and developing measures of lean production,” *J. Oper. Manag.*, vol. 25, no. 4, pp. 785–805, 2007.

[32] T. Bortolotti, P. Danese, and P. Romano, “Assessing the impact of just-in-time on operational performance at varying degrees of repetitiveness,” *Int. J. Prod. Res.*, vol. 51, no. 4, pp. 1117–1130, Feb. 2013.