LEAN APPLICATION IN A JOP SHOP: A CASE STUDY OF TYRE MOLD PLANT

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ABSTRACT

Lean methodology is a powerful continuous improvement method which is a combination of the many popular continuous improvement tools. However, Lean techniques are not much applied to manufacturers which produce high variety products, especially in the job shop production. This research focuses on the development and implementation of modified Lean methodology to improve production lines in a job shop manufacturing setting. Problems in the job shop production have been identified and the modified Lean methodology for job shop production has been developed. A case study in a tyre mold plant was used to validate the successful implementation of this modified Lean methodology to reduce lead time and setup time in job shop production. Application of our modified Lead approach leads to process improvement, reducing lead time by 58.55 percent at the milling station and by 64.53 percent at the plaster station. Process times at the milling and plaster stations were reduced by 69.65 and 6.58 percent, while setup times of both milling and plaster stations were reduced by 29.47 and 20.83 percent, respectively. The results obtained from this study can be applied to other process improvement endeavors. Finally, process improvement guidelines have been developed.

KEYWORDS: Lean application, Job shop, Tyre mold industry, Process improvement

1. Introduction

Nowadays, customers have higher expectation than the past. They want more volumes and more varieties at the same time. Businesses must not only develop the capacities but also promote flexibilities. The 11th edition of the Deloitte consumer review in 2015 reported that customers who expressed an interest in personalized products or services are willing to pay a premium price [1]. The trend of modern business model is toward mass

personalization. To serve the customers demand, many industries adapted to change their manufacturing setting from assembly line to job shop. Moreover, in present situation, businesses have been facing a large economic crisis with intense competition. Every company should find a way to increase its market share. Stopping improvement in the world that everyone goes forward is not different from stepping backward. Hence, continuous improvement is important.

There are several tools to be used for continuous improvement. Lean is a powerful continuous improvement method which is a combination of the many popular continuous improvement tools. Lean manufacturing is the well-known concept that helps businesses to prepare for intense competitive situation. However, Lean techniques are not much applied to companies which produce a high variety products [2], especially in the job shop production companies.

The reviewed literature shows Lean techniques are frequently applied to continuous process (also known as Mass production), especially in assembly line. A few researches suggest that Lean concept should be adopted in the job shop, but so far none of research has explained how to apply it in detail. In 2015, Dr. Daniela and Dr. John surveyed the level of Lean implementation in different manufacturing settings: Job shop, Batch shop, and Assembly line by sending a survey instrument to U.S. companies [3]. The results revealed that there would be significant difference between the degrees of utilization of Lean tools in a job shop when compared to an assembly line. Thus, this research is aimed at developing a guideline for Lean application in the job shop production type.

The tyre mold industry is an example of job shop manufacturing industries. Each product has different characteristic varied by the purchase orders. Hence, this research used a case study of a tyre mold manufacturer in Thailand to apply Lean concept. The scope of the study was on low pressure casting mold process starting from customer order to the delivery of mold from the factory. The tyre mold factory is getting more orders, the higher number of product types has intensely increased. Therefore, the factory needs higher flexibility in volume and style. According to the preliminary study, the factoryin the case has faced with delivery crisis. They could not deliver products to customers on time. The factory had spent a lot of money to change shipments in order to serve customers with on time delivery.

The purpose of this research is to develop a Lean framework guideline that can be used to solve with challenges in the case study. This will serve not only flexibility in reducing setup time but also reducing production lead time.

2. Lean Manufacturing

Basically, Lean Manufacturing is the production system that focuses on elimination of waste. The name “Lean” has implicit meaning on cutting “fat” from production activities [4]. The Lean Enterprise Institute [5] provides the conceptual framework for Lean into five principles including Identify value, Map the value stream, Create flow, Establish pull and Seek perfection. The Lean manufacturing is continuous improvement when value is specified, value streams are developed, and flow and pull are introduced. We must begin the process again and continue until production can reach a state of perfection.

2.1 Lean in various industries

The Review literature reveals that Lean is continuous improvement philosophy popularly and widely used in many companies not only manufacturing industry but also other industries [6-34], such as: Healthcare, Service, Logistics, etc. The applications of Lean in various industries are concluded in Table 1.

Table 1 The application of Lean in various industries [6-34]

Manufacturing setting	Number of papers
Assembly line	20
Service	5
Job shop	5

From the Table 1, Lean was implementing in various industries. However, many papers focus on Assembly line manufacturing setting. The Lean in job shop production has been discussed in a few studies. Especially in tyre mold industry. Hence, this study will focus on tyre mold production industry.

2.2 Job shop Lean

The Lean philosophy in job shop production has been discussed in a few studies. Many of the traditional Lean are used to improve in high-volume manufacturing. Lean is not suitable in made-to-order production because they use job shop manufacturing system [35]. Job shop is a low-volume high-variety manufacturing environment. In 2014, Djassemi Compared characteristics of high and low volume production [36]. There are some differences between high volume and low volume production in term of product variety and complexity. In low volume production, the manufacturing planning system set to job shop system. This makes more variety and complex in products. In order to produce range of products, a job shop requires highly skilled and versatile workforce and flexible manufacturing capability. Automation and specialization in some specific task are not supported in job shop environment. From the reason above, job shop should be careful when they apply Lean and choose Lean toolkit carefully.

While few studies applied Lean in job shop, Irani [35] studied and listed Lean tools that suitable in job shop. He discussed that the Value Stream Mapping has been a popular technique used in Lean but pretty useless in a job shop situation. It does not fit well when multiple routings are required and it is too complex. One-Piece Flow Cells and take time are too idealistic in the job shop. They may process hundreds of different items rather than higher production facilities. Sometime demand in the job shop is related with priority of job. So, FIFO may not work in the job shop. Kanban has limited applications because of a changing daily mix of orders. However, a few researches have been conducted to confirm Irani's work on Lean in job shop. Todorova and Dugger [3] conducted a survey level of Lean implementation in different manufacturing settings: job shop, batch shop, and assembly line. The results revealed that there would be significant difference between the degrees of utilization of Lean tools in a job shop when compared to an assembly line for Just in time, Heijunka, Jidoka, Poka-Yoke, Andon, Standardization work, Visual management, Kaizen and Teams. The limitations of their research are the population of the study included lean managers in U.S. companies, and the results may differ if the population was not limited to the U.S. The Next limitation is the personal biases of the respondents cannot be controlled. There are some difference results from Irani and Todorova that will describe in Table 2.

Table 2 Difference result between Irani [35] and Todorova et al [3]

Lean Tools use in the job shop	Irani	Todorova&Dugger
Value Stream Mapping	Not Suitable	Suitable
One piece flow/Continuous flow	Not Suitable	Suitable
FIFO	Not Suitable	*N/A*
Takt time/Just in time	Not Suitable	Not Suitable
Kanban	Not Suitable	*N/A*
Single-function Manual Machines	Not Suitable	*N/A*
Assembly line balancing/Heijunka	Not Suitable	Not Suitable
5S	Suitable	Suitable
TPM	Suitable	Suitable
Poka-Yoke	Suitable	Not Suitable
Quality at source/Andon	Suitable	Not Suitable
Employee involve	Suitable	Suitable
Strategic planning	Suitable	*N/A*
Visual control	Suitable	Not Suitable
Work standardization	Suitable	Not Suitable
Jidoka	Suitable	Not Suitable
Top-Down management	Suitable	*N/A*
Right-sized machines	Suitable	*N/A*
SMED	Suitable	Suitable
Team	*N/A*	Not Suitable
Kaizen	*N/A*	Not Suitable
MUDA/Value and Waste analysis	*N/A*	Suitable

From the Table 2, Irani claims that VSM and One piece flow may not work in the job shop. While Todorova and Dugger claim that they are workable in both job shop and

assembly line. Moreover, While, Todorova and Dugger claim that Poka-Yoke, Andon, Visual control, Work standardization and Jidoka will work in any job shop, Irani claims that they are not workable. Therefore, this research will study the Lean application in a different environment in order to confirm the Lean tools which will be application in job shop in tyre mold industry. A guideline for Lean application in a job shop environment in the tyre mold industry in Thailand will be proposed.

3. Use of the Modified Lean Methodology

Garnes and Vikhagen [11] implemented lean in hinge factory which have 2 product families. They separated value stream mapping into 2 maps depending on product families. Furthermore, The Lean Enterprise Institute claims that common cause variation is consistently contributing to manufacturing waste. It is generated from sources such as rework and scrap. So, Six Sigma is considered in this study for reducing variation in process by DMAIC structure. DMAIC structure is an acronym referred to five phases: Define, Measure, Analyze, Improve, and Control. This idea inspired researcher to create the modified Lean methodology for the job shop environment based on DMAIC structure. The modified Lean methodology is illustrated in Figure 1.

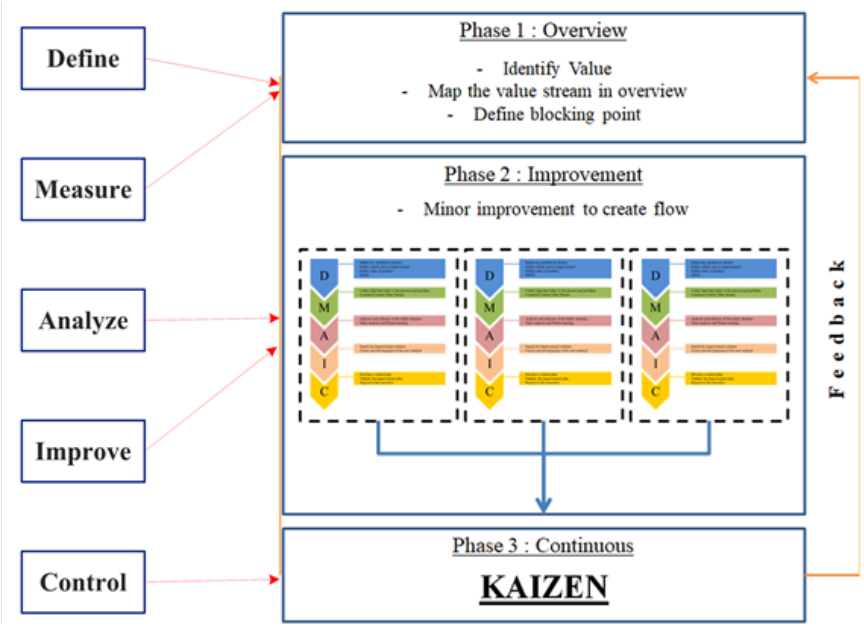

Figure 1 Modified Lean Methodology for job shop based on DMAIC structure

The methodology was designed for these challenges. It was separated into 3 phases which be described in following session.

The first phase is Overview phase. After Lean training, the first phase will begin to visualize process in overview. Voice of customer tool is used to define actual customer needs. Value stream mapping is developed for visualizing the production line. Management level such as manager or factory owner is necessary to involve in this phase.

The second phase is Improvement phase. The idea in Improvement phase is to improve process in detailes. We separated improvement in each process station like a snapshot. In job shop system, product flow have many independently workstation. That is different from assembly line. The detailed improvement will follow DMAIC structure. In this study, we used Voice of customers, SIPOC and Current VSM to define the process to be improved. Next, to understand the current situation of the station, we used time study. Value analysis and Ishikawa diagram are used to analyze what is causing the problem. The root causes are mitigated by using Lean tool such as SMED, 5S and Kanban. Last, we control the improvement by using work standardization and visual control.

Finally, the third phase is Continuous phase KAIZEN is introduced for seeking perfection in Lean philosophy. The data of improvement will be monitored and feedback to create the cycle of continuous improvement.

3.1 Use of the Modified Lean Methodology

A case study in a tyre mold plant was used to validate the successful implementation of this modified Lean methodology to reduce lead time and setup time in job shop production.

The first phase will begin to visualize process in overview. Voice of customer tool is used to define actual customer needs. The Value Stream Mapping workshop is developed by people who involve low pressure casting production line. The blocking point was defined by Pareto tool. Result from workshop revealed that every station has high lead time. After consulting with experts and company management, it is agreed to start the application of lean in two stations including milling and plaster station.

The second phase is applied in milling and plaster station. Following the structure of modified methodology, SIPOC is used to acquire knowledge of each station. The current state of milling station and plaster station are identified by creating Value Stream Map.

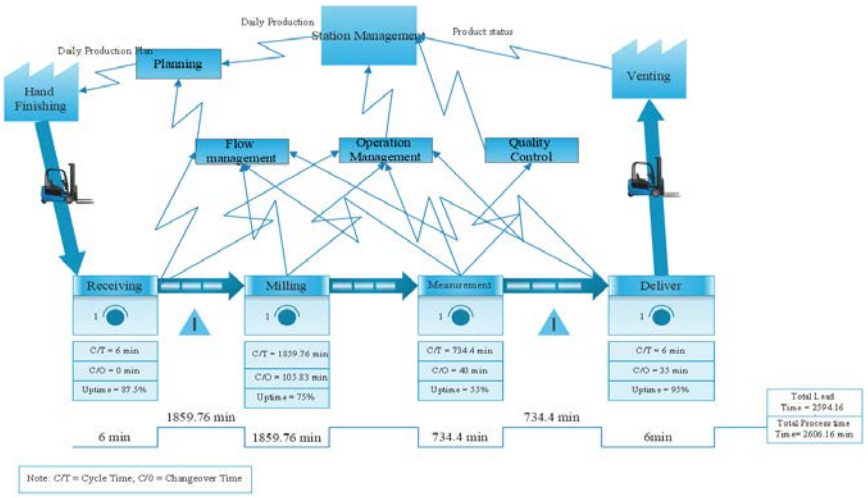

Figure 2 Current Value Stream Map of milling station

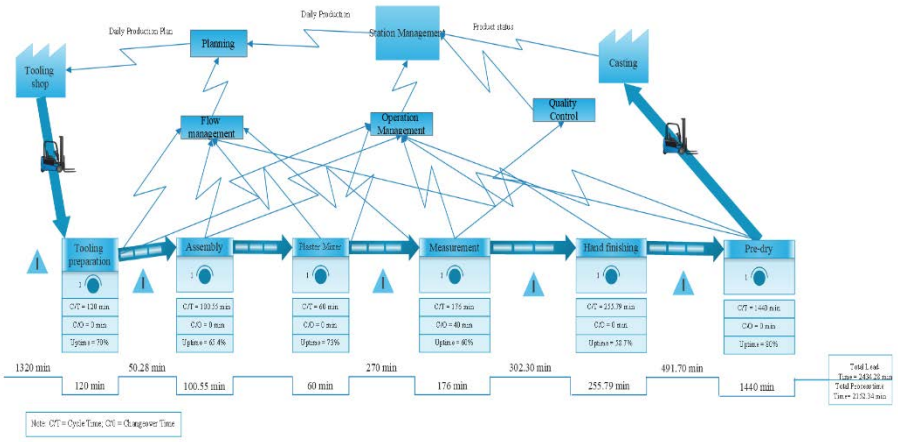

Figure 3 Current Value Stream Map of plaster station

To understand the current situation of the station, time study is a simple tool to achieve this goal. The result of observation showed the value activities in process. Wastes and values are identified by value analysis tool. The result shows that both milling and plaster station have high non-added value activities.

After wastes were identified, the improvement plan will be developed to eliminate wastes in process. The future state of Value Stream Map should represent the improvement process, shown in Figure 4 and 5.

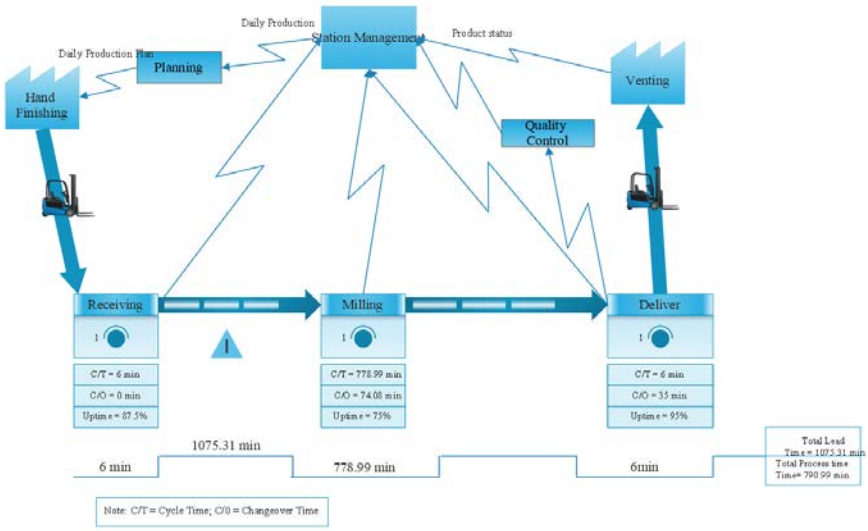

Figure 4 Future state Value Stream Map of milling station

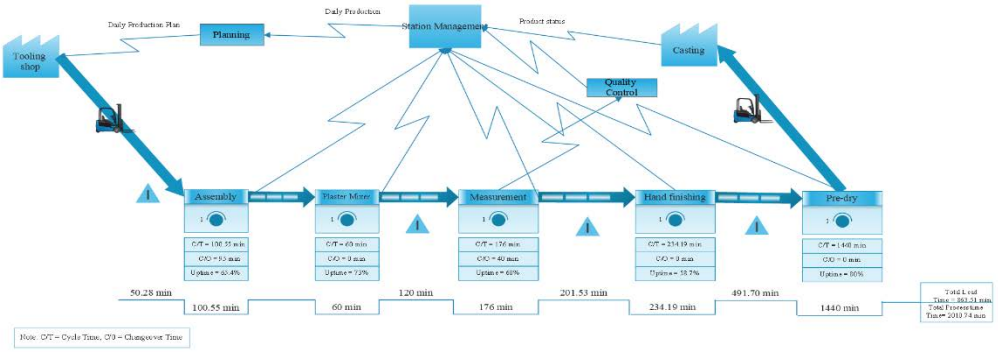

Figure 5 Future state Value Stream Map of plaster station

In the future state map, Non-value added activities are eliminated from process. The team has daily meeting to follow up improvement plan in early morning by using visual control management. Finally, kaizen is introduced to the production team for maintaining improvement as continuous improvement. By implementing modified methodology at two stations in case study, the team was able to reduce lead time and setup time that show in Table 3.

Table 3 Summary of results of improvement in case study.

Station		Before	After	%reduction
Milling	Lead time (Minutes)	2594.16	1075.31	58.55%
	Process (Minutes)	2606.16	790.90	69.65%
	Setup time (Minutes)	116.12	81.90	29.47%
Plaster	Lead time (Minutes)	2434.28	863.51	64.53%
	Process (Minutes)	2152.34	2010.74	6.58%
	Setup time (Minutes)	120.00	95.00	20.83%

4. Conclusion

This paper provides a modified Lean methodology for job shop manufacturing setting to improve production line. It focuses on improvement of production line by eliminating wastes in process. The result from this study confirms that Lean can apply in tyre mold factory which has job shop environment. But factories that need to apply Lean in job shop must choose carefully the Lean toolkit. There are many tools used in this study. Table 4 present the summary of useful Lean tools in job shop environment case study.

Table 4 List of suitable Lean tools in job shop environment case study.

Tools that would surely work in job shop	Tools that needs to adapt	Tools that may not work in job shop
5S	Value Stream Mapping	Takt time/Just in time
Employee involvement	Kanban	FIFO
SMED	Work standardization	Jidoka
Visual management	Poka-Yoke	One piece flow
Kaizen		Heijunka
Value and Waste analysis		

The results obtain from this study will help other factories which have job shop manufacturing in setting or changing their process to job shop in the future.

References

[1] Deloitte. The Deloitte consumer review. 11th Edition. London, UK: The Deloitte LLP; 2015.

[2] Matthias T, Mark S, Cristovao S, Martin JL, Lawrence DF, Steven M. Lean control for make-to-order companies: integrating customer enquiry management. Prod Oper Manag 2014;23:463-76.

[3] Todorova D, Dugger J. Lean manufacturing tools in jobshop, batchshop and assembly line manufacturing settings. The Journal of Technology, Management, and Applied Engineering 2015;31:1-19.

[4] Santos J, Wysk RA, Torres JM. Improving production with lean thinking. USA: John Wiley & Sons; 2006.

[5] Lean Enterprise Institute. Principles of Lean [Internet]. 2016 [cited 2017 Aug 5]. Available from: http://www.lean.org/WhatsLean/Principles.cfm.

[6] Anand G, Rambabu K. Design of lean manufacturing systems using value stream mapping with simulation: a case study. J Manuf Tech Manag 2011;22:444-73.

[7] Nakamanurak I. The Value Stream Mapping and simulation application for productivity improvement case study: frozen nile tilapia factory [Thesis]. Bangkok: King Mongkut's University of Technology North Bangkok; 2009.

[8] Audomkhunnatham M, Visuwan D. Lean manufacturing an improvement of work efficiency by using the balanced scorecard and lean manufacturing concept: a system dynamics simulation approach [Thesis]. Bangkok: Thammasart University; 2004.

[9] Gujarathi NS, Ogale RM, Gupta T. Production capacity analysis of a shock absorber assembly line using simulation. The Proceedings of the 36th conference on winter simulation conference; 2004 Dec 5-8; Washington, DC, USA. USA: IEEE; 2005.

[10] Paneru N. Implementation of lean manufacturing tools in garment manufacturing process focusing sewing section of men's shirt [Thesis]. Oulu, Finland: Oulu University of Applied Sciences; 2011.

[11] Garnes MA, Vikhagen T. Improving business processes: a case study of AS SpilkaIndustri [Thesis]. Molde, Norway: Molde University College; 2011.

[12] Tepjit S. Evaluation lean six sigma implementation using system dynamic modeling: case study in the hospital [Thesis]. Bangkok: King Mongkut's Institute of Technology North Bangkok; 2006.

[13] Cuatrecasas A. Design of a rapid response and high efficiency service by lean production principles: methodology and evaluation of variability of performance. Int J Prod Econ 2002;80:169-83.

[14] Sobeck DK, Jimmerson C. Innovating healthcare delivery using Toyota production system principles. Missoula, MT: The national science foundation innovation and organization change program; 2001 Jan. Report No.SES-0115352.

[15] Thavornkul N. Value stream mapping base on SCOR-model for improve manufacturing's efficiency case study: poultry industrial [Thesis]. Bangkok: King Mongkut's University of Technology North Bangkok; 2002.

[16] Taylor DH. Value chain analysis: an approach to supply chain improvement in agri-food chains. Int J Phys Distrib Logist Manag 2005;35:744-61.

[17] Shen SX, Han CF. China electrical manufacturing services industry value stream mapping collaboration. Int J Flex Manuf Syst 2006;18:285-303.

[18] Sittichokwarodom N. Process improvement in garment industry with lean six sigma concept [Thesis]. Bangkok: Chulalongkorn University; 2009.

[19] Melton T. The benefits of lean manufacturing. Chem Eng Res Des 2005;83:662-73.

[20] Fuengdenkhajon N. Responsiveness improvement in dental service industry by lean six sigma approach: a case study of special dental service clinic [Thesis]. Bangkok: Chulalongkornuniversity; 2004.

[21] Julien D, Holmshaw P. Six sigma in a low volume and complex environment. International Journal of Lean Six Sigma 2012;3:28-44.

[22] Wessel G, Burcher P. Six sigma for small and medium-sized enterprises. The TQM Magazine 2014;16:264-72.

[23] Prashar A. Redesigning an assembly line through Lean-Kaizen: an Indian case. The TQM Journal 2014;26:475-98.

[24] Roth N, Franchetti M. Process improvement for printing operations through the DMAIC lean six sigma approach: a case study from Northwest Ohio, USA. International Journal of Lean Six Sigma 2010;1:119-33.

[25] Raghavan VA, Yoon S, Srihari K. Lean transformation in a high mix low volume electronics assembly environment. International Journal of Lean Six Sigma 2014;5:342-60.

[26] Vamsi N, Sharma A. Lean manufacturing implementation using value stream mapping as a tool: a case study from auto components industry. International Journal of Lean Six Sigma 2014;5:89-116.

[27] Timans W, Antony J, Ahaus K, Solingen RV. Implementation of lean six sigma in small- and medium-sized manufacturing enterprises in the Netherlands. J Oper Res Soc 2012;63:339-53.

[28] Chowdary BV, George D. Improvement of manufacturing operations at a pharmaceutical company: a lean manufacturing approach. J Manuf Tech Manag 2011;23:56-75.

[29] Souza RP, Hékis HR, Oliveira LAB, Queiroz JV, Queiroz FCBP, Valentim RAM. (2013). Implementation of a Six Sigma project in a 3M division of Brazil. Int J Qual Reliab Manag 2013;30:129-41.

[30] Dora M, Van Goubergen DV, Kumar M, Molnar A, Gellynck X. Application of lean practices in small and medium-sized food enterprises. Br Food J 2014;116:125-41.

[31] Singh H., Singh A. Application of lean manufacturing using value stream mapping in an auto-parts manufacturing unit. Journal of Advances in Management Research 2013;10:72-84.

[32] Kaushik P, Khanduja D, Mittal K, Jaglan P. A case study: application of Six Sigma methodology in a small and medium-sized manufacturing enterprise. The TQM Journal. 2012;24:4-16.

[33] Man SM, Zain Z, Nawawi MKM. Cycle time reduction using lean six sigma in make-to-order (MTO) environment: Conceptual framework. AIP Conference Proceedings 2015; 2015 Sep 29 - Oct 1; Kedah, Malaysia. Malaysia; 2015.

[34] Thomas A, Barton R, Chuke-Okafor C. Applying lean six sigma in a small engineering company – a model for change. J Manuf Tech Manag 2008;20:113-29.

[35] Irani S. Adapting lean for job shop and high-mix low-volume small and medium enterprises. The Fabricator 2011;20:44-5.

[36] Djassemi M. Lean adoption in small manufacturing shops: attributes and challenges. The Journal of Technology, Management, and Applied Engineering 2014;30:1-10.

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