Leanness Assessment in an Auto Parts Manufacturer

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Abstract

This study applies main Lean Manufacturing (LM) techniques to investigate the accordance of an auto parts manufacturer from Iranian automotive industry. Although the concept of LM has been successfully applied in previous studies, concurrent investigation of its requirements is less examined, especially in developing countries. In addition, the majority of previous studies have applied qualitative leanness assessment tools to investigate LM implementation while it is necessary to focus on both qualitative and quantitate techniques. In this regard, this study has applied seven wastes of LM, Value Stream Mapping (VSM) and Overall Equipment Effectiveness (OEE) to investigate the accordance of an auto parts manufacture with LM requirements. According to the obtained results, this manufacturer is moderately in accordance with LM philosophy.

Keywords
Lean Manufacturing (LM), Wastes, Value Stream Mapping (VSM), Overall Equipment Effectiveness (OEE)

1. Introduction

Performance measurement is an essential task that should be considered in any company which is seeking for success in today’s competitive markets (Galankashi et al. 2018a). In this regard, performance measurement has been successfully applied in different companies, industries, supply chains, etc (Soleimaninanadegany et al. 2017). There are different strategies linked with performance measurement philosophy. These strategies include but not limited to Lean Manufacturing (LM), Agile Manufacturing (AM), Leagile Manufacturing, Green Manufacturing (GM), Sustainable Manufacturing (SM) and many others (Hashemzahi et al. 2020; Galankashi and Helmi, 2016a). Among all these strategies, LM has been more investigated in manufacturing environments (Behrouzi and Wong, 2013). In this regard, with the progress of LM and its required techniques, Lean Performance Measurement System (LPMS) has been applied to check the accordance of companies, supply chains and organization with LM philosophy (Bhasin, 2008).

Although LM concept has been vastly investigated in previous literature, few studies have investigated its real implementation in different industries. In addition, the majority of previous studies have checked the implementation level of LM by leanness assessment tools. However, the majority of these assessment tools apply qualitative tools such as Likert-based questionnaire to check the accordance of companies with LM philosophy. As these approaches are mainly based on self-assessment techniques, many managers, practitioners and operators prefer to exaggerate their accordance as being lean means to have a proper performance. By the way, the reality might be different as many companies, especially in developing countries, are not even familiar with LM techniques. In this regard, it is better to assess the accordance of this companies using lean related calculations. In other words, as many managers, practitioners and operators of these companies are not familiar with LM and its related techniques, it is better to assess their leanness level using both qualitative and quantitative lean-related calculations. Therefore, it is essential to know about major requirements of leanness, calculation process and potential outputs to efficiently investigate the accordance of manufacturing companies with LM philosophy.

While lean related calculations are vastly trained in universities, they are less examined in real world industrial environments. This is mainly due to the fact that many managers prefer to focus on cost minimization approaches instead of lean related concerns. This attitude can somehow be justified as many managers see the cost as the most important issue to be optimized. However, today's competitive markets have forced companies to see other issues in performance measurement process. Therefore, LPMS can assist managers to improve both cost and non-cost based performance as it includes many important issues of manufacturing such as cost, quality, lead-time, customers, etc.

1.1 Objectives

The main aim of this study is to check the accordance of an auto parts manufacturer with LM philosophy. However, as the specific objective, this study has applied seven wastes of LM, Value Stream Mapping (VSM) and Overall Equipment Effectiveness (OEE) to investigate the accordance of an auto parts manufacture with LM requirements

2. Literature Review

As an important strategy, LM has been successfully implemented in different manufacturing companies from different industries (Bader et al., 2020; Pondhe et al., 2006). LM was initially introduced by Taichi ohno and Eiji toyoda at Toyota Company in the last days of World War II. It was initially based on waste elimination, over processing, unnecessary movements of both people and materials, lead-time, extra inventory and over production. These issues were then updated and changed to 7 wastes of LM. Next, more investigation was made by Womack who focused on LM in US companies. As the authors of the book entitled "The machine that changed the world", Womack et al. (1991) showed how Toyota Production System (TPS) and older manufacturing styles are different. In addition, this book showed that LM is a combination of Ford manufacturing style and Japanese way of managing Toyota Company.

The current available literature on LM and its related tools and techniques is very vast. In this regard, there are numerous studies on LM, its requirements, implementation, assessment and assurance. According to previous literature, leanness assessment approaches include four major approaches as follows (Behrouzi and Wong, 2013). The first leanness assessment approach is mainly developed based on its implementation level. To be clearer, the majority of previous studies on this approach apply available knowledge to check the percentage of implementing LM techniques in a manufacturing company. As an example, Galankashi et al. (2018b) has applied an activity based framework to assess the leanness of manufacturing companies. As the second approach to assess the leanness of companies, there are many studies which have applied Leanness Key Performance Indicators (LKPIs) to check the effect of LM implementation. In other words, these studies have examined the quantity of these KPIs before and after LM implementation. For example, Cortes et al. (2016) incorporated lean tools and related KPIs to improve the performance of companies. As the third leanness approach, there are some studies which have provided a single combined index to show the overall leanness level. As an example, Gurumurthy and Kodali (2009) applied a benchmarking tool to assess the outputs of implementing LM. Finally, regarding the fourth approach of leanness assessment, the value and non-value adding activities have been highlighted by VSM. In other words, previous studies have suggested to apply VSM to improve value-adding activities which lead to a better leanness level (Deshkar et al. 2018). Table 1 provides a summary of previous study.

As a summary of literature review section, according to previous literature, it is necessary to apply specific frameworks for the aim of performance measurement. In other words, performance measurement process should be matched with applied manufacturing strategy of companies (Galankashi et al. 2013). In this regard, a lean manufacturer should try to achieve different necessities of LM concept. As discussed, LM and its related techniques have been vastly investigated in previous literature. However, as there are many companies where managers are not familiar with LM, sole application of leanness assessment frameworks is not enough, especially when leanness assessment process is based on self-assessment tools such as questionnaires. To fill this gap, this study applies main LM techniques to investigate the leanness an auto parts manufacture from Iranian automotive industry with LM philosophy. The applied methodology and developed research methodology of this study is completely practical as it has been successfully applied in a real case study.

Table 1. Literature Summary

Author	Year	Findings	Advantages
Hj. Bakria et al.	2012	• Integrated LM-Maintenance system • Wastages of manufacturing	• Linkage between Total Preventive Maintenance (TPM) and LM
Arunagiri & Gnanavelbabub	2014	• Ranking of different LM waste is provided	• The effect of each waste is clearly discussed
Galankashi et al.	2016b	• Lean supplier selection criteria are developed in this research • Lean supplier selection model is provided in this research	• Fuzzy environment • Multi-Criteria Decision Making (MCDM) approach
Mrugalska et al.	2017	• Different step to implement LM • Lean implementation in SMEs	• Integration of LM and Industry 4.0
Raucha et al.	2017	• LM implementation enablers • LM implementation barriers	• The necessity of training for operators who are working in Industry 4.0 companies
Tortorella et al.	2017	• Linkage between LM and Industry 4.0 • The effect on LM implementation in Industry 4.0 companies	• Comprehensive literature review • Properly discussed questionnaire
Wagner et al.	2017	• The effect of Industry 4.0 on LM implementation • Just in Time (JIT) implementation framework	• Comprehensive literature review • Process based discussion

Table 1. Continued

Author	Year	Findings	Advantages
Galankashi and Helmi	2017	• LM practices • Leanness assessment from an operational perspective	• Deep literature review • Practical framework
.Galankashi et al.	2018b	• Leanness assessment framework • Single index leanness score	• Case study approach • Application in automotive industry
De Souza et al.	2019	• Integration of LM and sustainability • Proper application LM tools	• Fluent research methodology
Gleeson et al.	2019	• A lean performance improvement framework • Service time minimization using lean tools	• Illustrative example • Six sigma lean process
Syndi et al.	2020	• Service time reduction via LM techniques • Waste elimination in a fire station	• Proper application of VSM and 5S
Rezaei et al.	2020	• Lean supplier selection criteria • Lean order allocation model	• Real case study • Sensitivity analysis
Galankashi et al.	2020	• Aggregate Production Planning (APP) Model for LM • Lean weighting of objective functions	• Real case studies • New model in the area of production planning

3. Methods

As discussed, this research applies LM techniques to assess the leanness of an auto parts manufacture from Iranian automotive industry. In this regard, this study has been completed in four phases as follows. Different research steps are depicted in Figure 1.

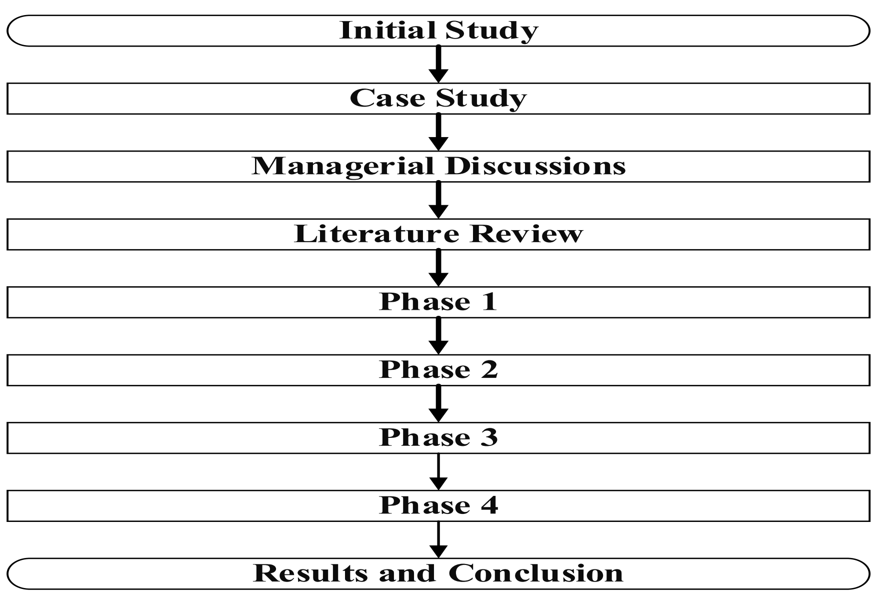

Figure 1. Research Steps

3.1 Phase one: Investigating the seven wastes of LM

According to previous sections, LM aims to minimize waste as much as possible. In this regard, the seven wastes of LM including transportation, inventory, motion, waiting, over processing, overproduction, and defects have been investigated in the case study. This investigation is beneficial as it helps performance improvement process to find non-value adding processes and complete VSM which is discussed in next phase.

3.2 Phase two: VSM

Following to the previous phase, the VSM of the production line is completed. As an important output of this phase, different activities of the case study are investigated and decision makers can easily see both value and non-value adding activities on the map.

3.3 Phase three: Finding production bottlenecks

Following to the previous phases, different bottlenecks of the production line are determined. According to previous literature, limited capacity of a manufacturing machine decreases overall pace of the production line. In this regard, bottleneck is a process of a production line in which its low capacity decreases the capacity of whole production line.

3.4 Phase four: OEE calculation

Finally, following to the determining process of bottleneck machine, the OEE of the production line is calculated. Microsoft Excel has been applied to calculate OEE using its required data and related equations discussed in next sections.

4. Data Collection

An auto parts manufacture from Iranian automotive industry has been selected to be investigated. As discussed, the accordance of this company with LM requirements has been investigated in this research. The required data are directly gathered from this case study.

5. Results and Discussion

The obtained results of this study are discussed in this section. As discussed above, this research has been completed in four linked phases. In this regard, the results are also discussed based on major outputs of each phase as follows. The investigated case study is an auto parts manufacturer from Iranian automotive industry. This manufacturer produce automobile lights and send them to one of the biggest automotive manufacturer of Middle East. As discussed in research methodology section, the first phase of this study aims to investigate available wastes in the case study. To do so, seven wastes of LM have been investigated for potential existence in the case study. As the first investigated waste, there were some defect products in the production line. After a deeper investigation in quality control department, all these nonconforming products were more investigated to be reworked. However, as a common action of this case study, a product will be recycled if it cannot be reworked. Following, regarding the over production waste, 9 days of production plan has been considered to compare the scheduled production quantity and the real production. As shown in Table 2, almost in all periods, this company is producing both right and left automobile lights more than its scheduled plan. According to LM concept, overproduction is a type of waste which should be avoided. In this regard, this issue has been reported to top management and the corrective actions will be conducted to reschedule the production and capacity planning. In addition, as tabulated in Table 2, there are some days with no production quantity. Although overproduction is considered as a waste, no production is also a waste as the company have to pay for its workers, managers and the overhead costs.

Table 2. Scheduled and real production quantity (9 days period)

Day	Real Production (left light)	Scheduled Production (left light)	Real Production (right light)	Scheduled Production (right light)
1	136	350	724	400
2	888	350	1112	400
3	492	550	616	600
4	1064	200	584	200
5	-	200	576	200
6	232	200	-	200
7	160	200	520	240
8	592	240	204	240
9	-	240	380	240

Over processing is the next waste which is investigated in this case study. After a deep investigation of production line, there were no over processing in the system. However, as different operators might be assigned to new jobs which they are not familiar with, there are some over processing at the first days. Once the operators got familiar with the job, they could easily handle the assigned job without any over processing. Transportation is the next investigated waste of this study. There were four types of transportation waste in this case study. These wastes include raw material transportation waste, inter production transportation waste, after production transportation waste and inter warehouse transportation waste. Therefore, the transportation waste is the biggest portion of overall waste of this company. Following, inventory is the next investigated waste of this company. As the company is not following its production plan tabulated in Table 2, extra inventories are transferred to the warehouse. These extra inventories are somehow justifiable as there are many maintenance issues in this company. These issues force the maintenance department to stop production line and fix the machines. In this regard, extra inventories are applied to compensate the stoppage times. In addition, as the automobile lights are not perishable, the company can keep them easily. However, holding costs are still high in this company. Extra movement is the next investigated waste of this company. According to the observations completed in different days of investigation, there were no extra movement in the production line as all operators have been properly trained by the company.

Finally, waiting is the last type of waste investigated in this study. According to the observations completed in different days, there are two types of waiting wastes in this company. Firstly, the lights' quality inspection process which is automatically completed by machines takes at least 10 minutes to be completed. The assigned operators are idle during this time that is considered as a waste. In addition, all operators should wait till the raw materials are supplied from the warehouse. A low speed transportation from warehouse to production line can increase this waiting time and end to extra waste of time. As discussed, the second phase of this research aims to provide a VSM to the case study. In this regard, following to the first phase, the VSM of the production line is depicted in Figure 2. As a significant output of this phase, diverse processes of the case study are examined and managers can simply check both value and non-value adding activities on the map.

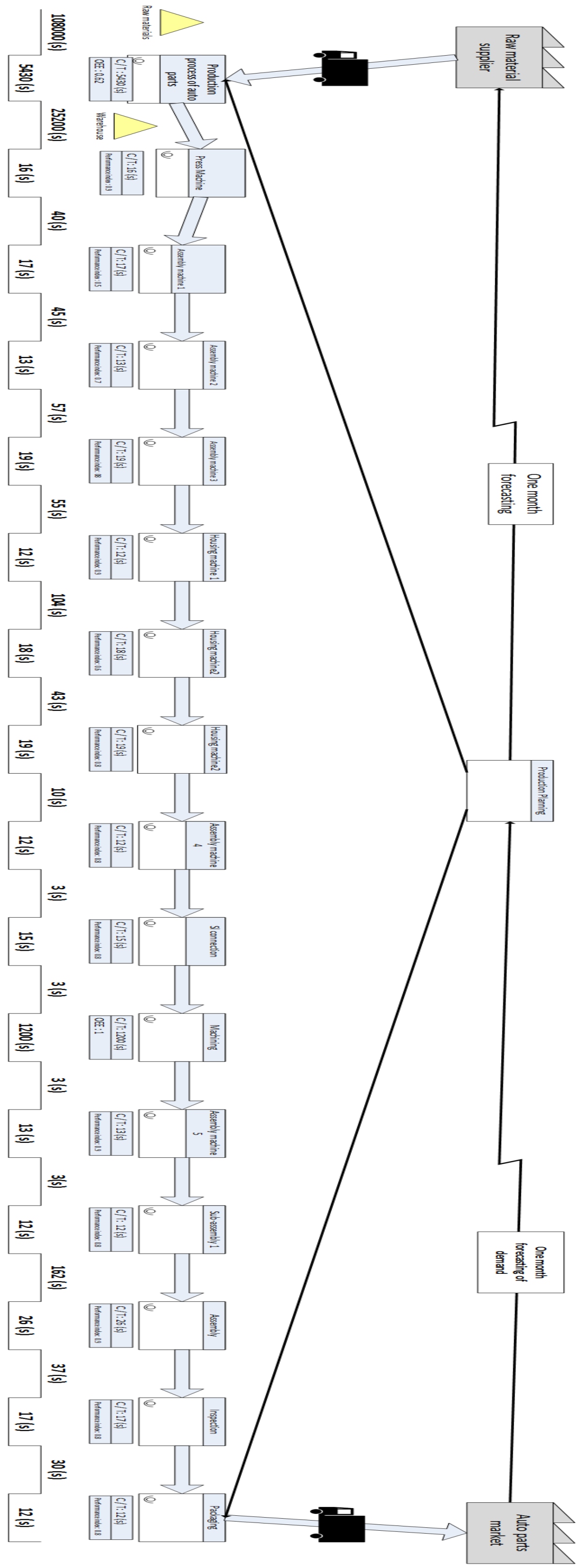

Figure 2 VSM

As discussed, the third phase of this study aims to determine available bottlenecks of the production line. Based on a common definition, the overall pace of the production line is decreased with regard to limited capacity of a manufacturing machine. There were two bottlenecks in the production line. These bottlenecks include the heating process and inspection stations. The low speed of the operator working in the heating process station causes the delay in overall process. In addition, the inspection station's delay is also caused by the operator. These issues were reported to managers and they increased the training hours of operators to improve their working skills. Finally, the OEE of different equipment of the case study are calculated following to determining process of the bottleneck machine. As discussed, Microsoft Excel is applied to calculate OEE using its required data and subsequent equations. So, following the required calculations in Microsoft Excel, Tables 3 and 4 show the OEE of four machines of this case study.

$$Availiability = \frac{Actual\ Production\ Time}{Possible\ Production\ Time} * 100 \quad (1)$$

$$Performance = \frac{Actual\ Output}{Possible\ Output} * 100 \quad (2)$$

$$Quality = \frac{Quality\ products}{Actual\ output} * 100 \quad (3)$$

$$OEE = Availiability \times Performance \times Quality \quad (4)$$

Table 3 OEE of first two machines

Name	Haiyon (G-TPM)	Name	TNR45 (O-BMC)
Scheduled time	158.5	**Scheduled time**	267
Idle time	20.5	**Idle time**	10
Production time	138	**Production time**	257
Scheduled production	7925	**Scheduled production**	14564
Real production	5491	**Real production**	10015
Defect items	165	**Defect items**	491
Net production	5326	**Net production**	9524
Availability	0.87	**Availability**	0.96
Performance	0.69	**Performance**	0.69
Quality	0.97	**Quality**	0.95
OEE	0.59	**OEE**	0.63

Table 4 OEE of second two machines

Name	Haitian (650)	Name	KM (800)
Scheduled time	260	**Scheduled time**	248.5
Idle time	39	**Idle time**	26
Production time	221	**Production time**	222.5
Scheduled production	15600	**Scheduled production**	14496
Real production	12668	**Real production**	11066
Defect items	820	**Defect items**	209
Net production	11848	**Net production**	10857
Availability	0.85	**Availability**	0.89
Performance	0.81	**Performance**	0.76
Quality	0.94	**Quality**	0.98
OEE	0.65	**OEE**	0.67

6. Conclusion

This research applied major LM practices to assess the leanness of an auto parts manufacture from Iranian automotive industry. As a robust contribution of the paper, this research has focused on practical issues of LM. In other words, the leanness assessment process is completed using practical issues of manufacturers. The research methodology was designed in four main phases discussed in previous section. In this regard, this study has applied seven wastes of LM, VSM and OEE to assess the accordance of an auto parts manufacture with LM necessities. Based on the discussed results, this manufacturer is moderately in accordance with LM philosophy as the waste are somehow available in this company, there are some bottlenecks and finally, the OEE of its equipment are almost meidum. Therefore, this research has focused on practical viewpoints to assess the leanness of companies. In other words, while there are many approaches to assess the leanness, the outputs of this study are applicable to assess the leanness from a practical viewpoint. Therefore, the research and practical contributions of this study include the developed research methodology and applied approach, respectively. As a direction for future research, similar approach can be applied for other strategies such as agile, Leagile, green and sustainable production philosophy. In addition, the developed approach of this study can be tested in other manufacturing industries. Finally, it is recommended to implement this approach in service industries.

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References

Arunagiri, P., Gnanavelbabub, A. (2014). Identification of Major Lean Production Waste in Automobile Industries using Weighted Average Method. Procedia Engineering 97: 2167 – 2175.
Bader, B. H., Badar, M. A., Rodchua, S., & McLeod, A. (2020). A study of the balancing of lean thinking and stakeholder salience in decision-making. The TQM Journal.
Bakri, A. H., Rahim, A. R. A., Yusof, N. M., & Ahmad, R. (2012). Boosting lean production via TPM. *Procedia-Social and Behavioral Sciences*, 65, 485-491.
Behrouzi, F., & Wong, K. Y. (2013). An integrated stochastic-fuzzy modeling approach for supply chain leanness evaluation. *The International Journal of Advanced Manufacturing Technology*, 68(5-8), 1677-1696.
Bhasin, S. (2008). Lean and performance measurement. *Journal of Manufacturing Technology Management*.
Cortes, H., Daaboul, J., Le Duigou, J., & Eynard, B. (2016). Strategic lean management: integration of operational performance indicators for strategic lean management. *IFAC-PapersOnLine*, 49(12), 65-70.
Deshkar, A., Kamle, S., Giri, J., & Korde, V. (2018). Design and evaluation of a Lean Manufacturing framework using Value Stream Mapping (VSM) for a plastic bag manufacturing unit. *Materials Today: Proceedings*, 5(2), 7668-7677.
DeSouza, João Paulo Estevam., Dekkers, Rob. (2019). Adding Sustainability to Lean Product Development. *Procedia Manufacturing*. 39: 1327–1336.
Galankashi, M. R., & Helmi, S. A. (2016). Assessment of hybrid Lean-Agile (Leagile) supply chain strategies. *Journal of Manufacturing Technology Management*.
Galankashi, M. R., & Helmi, S. A. (2017). Assessment of lean manufacturing practices: an operational perspective. *International Journal of Services and Operations Management*, 28(2), 163-184.
Galankashi, M. R., Fallahiarezoudar, E., Moazzami, A., Helmi, S. A., Rohani, J. M., & Yusof, N. M. (2018). An efficient integrated simulation–Taguchi approach for sales rate evaluation of a petrol station. *Neural Computing and Applications*, 29(4), 1073-1085.
Galankashi, M. R., Helmi, S. A., Hisjam, M., & Rahim, A. R. A. (2018). Leanness assessment in automotive industry: case study approach. *International Journal of Value Chain Management*, 9(1), 70-88.
Galankashi, M. R., Hisjam, M., & Helmi, S. A. (2016, March). Lean supplier selection: a data envelopment analysis (DEA) approach. *In Proceedings of the sixth international conference on industrial engineering and operations management (IEOM)*.
Galankashi, M. R., Madadi, N., Helmi, S. A., Rahim, A. R. A., & Rafiei, F. M. (2020). A Multiobjective Aggregate Production Planning Model for Lean Manufacturing: Insights From Three Case Studies. *IEEE Transactions on Engineering Management*.
Galankashi, M. R., Ziaei, F., Helmi, S. A., & Baniani, A. M. (2013). Assessment of supply chain strategies and analysis on the performance of companies deployed strategy using activity based approach. *Sains Humanika*, 64(2).
Gleeson, Frank., Coughlan, Paul., Goodmana, Lizbeth., Newella, Anthony., Hargadena, Vincent. (2019). Improving manufacturing productivity by combining cognitive engineering and lean-six sigma methods. *Procedia CIRP*. 81: 641–646.
Gurumurthy, A., & Kodali, R. (2009). Application of benchmarking for assessing the lean manufacturing implementation. *Benchmarking: An International Journal*.

Hashemzahi, P., Azadnia, A., Galankashi, M. R., Helmi, S. A., & Rafiei, F. M. (2020). Green supplier selection and order allocation: a nonlinear stochastic model. *International Journal of Value Chain Management*, 11(2), 111-138.
James P. Womack, Daniel T. Jones, Daniel Roos, & Massachusetts Institute of Technology. (1991). *The machine that changed the world: The story of lean production*. Harper Collins.
Mrugalska, Beata., Wyrwicka, Magdalena K. (2017). Towards Lean Production in Industry 4.0. *Procedia Engineering* 182: 466 – 473.
Pondhe, R., Asare, S., Badar, M., Zhou, M., & Leach, R. (2006). Applying lean techniques to improve an emergency department. In IIE Annual Conference. Proceedings (pp. 1-6). Institute of Industrial and Systems Engineers (IISE).
Raucha, Erwin., Dallasegaa, Patrick., T. Matta, Dominik. (2017). Critical Factors for Introducing Lean Product Development to Small and Medium sized Enterprises in Italy. *Procedia CIRP*. 60: 362 – 367.
Rezaei, A., Rahiminezhad Galankashi, M., Mansoorzadeh, S., & Mokhatab Rafiei, F. (2020). Supplier Selection and Order Allocation with Lean Manufacturing Criteria: An Integrated MCDM and Bi-objective Modelling Approach. *Engineering Management Journal*, 1-19.
Soleimaninanadegany, A., Hassan, A., & Galankashi, M. R. (2017). Product allocation of warehousing and cross docking: a genetic algorithm approach. *International Journal of Services and Operations Management*, 27(2), 239-261.
Syndi E F, Ginting., Vindy B, Ramadhani., Uni P P, Tarigan., Grace A., Elisabet, Simarmata., Lucya L, Saragihf. (2020). Implementation of Lean Service and 5S Methods to Increase the Efficiency of Service Time in Fire Department. *AIP conference proceeding*.
Tortorella, Guilherme Luz., Fettermann, Diego. (2017). Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. *International Journal of Production Research*. pp: 1-13.
Wagner, Tobias., Herrmann, Christoph., Thiede, Sebastian. (2017). Industry 4.0 impacts on lean production system. *Procedia CIRP*. 63: 125-131.

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