Implementation of Lean Manufacturing tools in emerging countries: evidence from Uzbek SMEs

Hoshimov A.[a,b], Cagliano A.C.[a], Schenone M.[a], Inoyatkhodjaev J.[b]

[a]*Department of Management and Production Engineering, Politecnico di Torino, Corso Duca Degli Abruzzi 24, 10129 - Torino – Italy (abror.hoshimov@polito.it, anna.cagliano@polito.it, maurizio.schenone@polito.it)*

[b]*Department of Aerospace and Mechanical Engineering, Turin Polytechnic University in Tashkent, Kichik khalka yuli st.17, 100095 – Tashkent - Uzbekistan (abror.hoshimov@polito.it, j.inoyatkhodjaev@polito.uz)*

Abstract: It is known that Lean Manufacturing (LM) practices play a significant role in achieving lower costs, higher flexibility, and efficiency in production processes, in order to fit the requirement of today's dynamic customer demand. A lot of literature contributions deal with the application of Lean in developed countries. However, few studies have been focused on integrating various Lean tools to optimize manufacturing processes in developing countries. In particular, a limited number of case studies address manufacturing in Small and Medium Enterprises (SMEs) in Central Asian countries. Thus, the purpose of this work is to investigate through a case study how LM can enhance the operational efficiency of an Uzbek aluminium profiles manufacturer. The proposed combination of different LM techniques, such as Value Stream Mapping (VSM), 5 W +1 H, and 5S, improved the overall performance of the production process at issue. Wasted time was reduced to 2% and 8% in press and painting shops respectively. Additionally, the total daily production rate was increased up to 30.1 t/day. LM application to emerging countries' SMEs improves production effectiveness and helps to achieve higher levels of production standards, which leads to an increase export capability and market share in the international context.

Keywords: Lean Manufacturing, waste, SMEs, emerging countries.

1. Introduction

Today's global market is changing daily and it requires more flexibility, shorter lead time, lower costs, and high-quality standards in production to stay competitive. As a consequence, companies tend to improve their performance in terms of both economic and technical aspects. Lean Manufacturing (LM) principles are one of the essential tools to achieve this goal. LM tools have been extensively used in different industries all over the world during the past two decades (Panizzolo, Garengo, Sharma, & Gore, 2012).

The application of various LM techniques has attracted much attention to reduce and eliminate wastes in production processes. The current literature on the implementation of LM tools has focused on the fundamental issues of their application. Many authors consider specific LM tools for identifying and reducing non-value added activities, such as Value Stream Mapping (VSM) (Abhishek & Pratap, 2020; Baby, Prasanth, & Jebadurai, 2018; Dotoli, Epicoco, Falagario, & Costantino, 2013); 5S, and 5 Why (5W) (Bonilla-Ramirez, Marcos-Palacios, Quiroz-Flores, Ramos-Palomino, & Alvarez-Merino, 2019; Cagliano, Grimaldi, & Schenone, 2018). Moreover, a lot of studies have been conducted on manufacturing processes in developed countries (De Carlo, Arleo, Borgia, & Tucci, 2013; Yamazaki et al., 2017). However, few literature contributions have addressed the integration of different LM tools to widen their implementation range and increase sustainability. Additionally, little evidence is available regarding the application of LM practices in emerging countries' industries (Panwar, Jain, & Rathore, 2015). However, LM has become a popular methodology in different global companies (Zhou, 2016), so that its application cannot neglect developing or emerging countries. LM practices in Central Asian Small and Medium Enterprises (SMEs) have a relatively short history, and many challenging areas are largely uncovered by academicians. As very few case studies regarding LM tools in SMEs of emerging countries have been performed in the past, this leads to a potential need for further research (Bloom, Schweiger, & Van Reenen, 2012). With the aim of contributing to close such a gap, the present work proposes an approach integrating the main LM techniques to improve the operational efficiency of an Uzbek aluminium profile manufacturer through a case study. Firstly, the authors analyse the current state of the manufacturing process through focused interviews with company experts and direct visual inspection, in order to identify and quantify the potential wastes. Secondly, they explore the effectiveness of combining VSM, 5S, 5W+1How(H), and Standard Operation Procedures (SOP) in order to reduce and eliminate wastes. VSM is a powerful tool to identify potential wastes and quantify the benefits of their reduction, while 5W+1H allows defining the root causes of non-value-added activities, whereas 5 S plays an important role in order to create a sustainable implementation of Lean and support continuous improvement in manufacturing. Finally, SOP assists in smoothing the production process through standardizing its tasks.

The reminder of the paper is organized as follows. The next section summarizes the literature background about LM and its application in emerging countries' SMEs. In Section 3 the research methodology is described, while Section 4 presents the case study and performs an in-depth analysis on the major benefits and challenges experienced. Finally, Section 5 discusses the research findings and conclusions.

2. Literature review

2.1 Lean Manufacturing

LM is mostly related to reduction and elimination of non-value-added activities to provide products in a shorter lead time, at a lower cost and with a higher quality (Antony, 2011). Defective products, excess inventory, and machine breakdowns have been long considered among the main production wastes. In an early work on the topic, Womack et al. (1990) studied the global automotive industry and introduced the term "Lean Production" in order to describe the best practices guiding automotive companies in obtaining superiority with respect to their competitors. Generally, LM pursues identification and reduction of different types of waste in a factory by implementing a set of specific tools. LM techniques eliminate excess activities, align processes in a continuous flow and solve problems through constant and incremental improvement (Sohal, 1996).

2.2. LM tools integration in production and logistics

With the purpose of giving a background to the present research, the key studies about the implementation of combined LM tools are reviewed.

Kovács et al. (2020) conducted a case study that covered the combination of 13 LM methods and Facility Layout Design (FLD) to minimize the unnecessary wastes in production. Moreover, Pinto *et al.*, (2019) suggested to integrate People Involvement, Single Minute of Exchange Die (SMED) and 5S techniques to reduce the tool change time. By exploring a broad range of tools, Arunagiri and Gnanavelbabu (2014) ranked 5S, Overall Equipment Effectiveness (OEE), 8 Step Problem Solving Method, Pareto Analysis, Kaizen, Process Mapping, and VSM according to the effects generated by their implementation on the automotive industry. Based on this ranking, 5S and OEE provided the highest impact compared to the other tools. Additionally, Unified Modelling Language (UML) for describing warehouse operations was combined with VSM and Genba-Shikumi respectively to identify and rank criticalities. The resulting approach showed its simplicity and effectiveness, emphasizing that the problems affecting the case company warehouse were caused by the absence of an integrated and automated warehouse management (Dotoli et al., 2015). Other researchers addressed the integration of different LM techniques in warehouse design and proposed new frameworks for Lean warehousing (Cagliano et al., 2018). In particular, they combined 5W, 5S, and VSM as a starting point to structure Lean warehouse processes.

2.3. Literature regarding LM implementation in emerging countries

LM tools have been widely implemented in heterogeneous fields and differently sized industries, as well as there are many studies focused on their impacts on SMEs. Shah and Ward (2003) showed LM tools are extensively implemented in all industries despite of their type or size. Similar results were found by (Sohal and Egglestone, 1994; Bonavia and Marin, 2006; Moriones, Pintado and Cerio, 2008). However, Gebauer et al. (2009) claimed that structural factors, such as size of industry and company type, have a fair influence on the success of LM tools. Despite this result, the majority of the existing recent literature still propose widespread applications of LM techniques regardless the kind of industries, including SMEs (Elkhairi, Fedouaki, & El Alami, 2019; Pearce, Pons, & Neitzert, 2018). In the last years the application of LM tools has become quite popular also in emerging countries' SMEs. The available investigations were obtained through case studies, mainly regarding Indian and Indonesian SMEs. In particular, Putri and Dona (2019) discussed the application of LM techniques to facility layout redesign in the Indonesian home-food industry and found that SOP was effective in order to minimize wastes. On the other hand, Panizzolo *et al.* (2012) investigated the adoption of LM in India and proved the significance of LM tools in driving an outstanding improvement in the production process. Nevertheless, there is non-existent literature that describes the application of LM tools in Central Asia SMEs, which remains an unstudied topic. Thus, there is an urgent need to address the application of the LM approach in these countries' manufacturing plants to provide valuable results to both researchers and practitioners.

So, the performed literature review discloses that in spite of the increasing attention that LM has received in the last decades, it is necessary to carry out more studies in developing countries. In this context, limited works have addressed the combination of more than one LM technique to improve the production process. Thus, the present work helps to fill such a gap by proposing an integrated approach based on VSM, 5S, 5W+1H, and SOP through a case study. In order to provide its practical implementation, the first results of the ongoing validation process are discussed.

3. Research methodology

For conducting the case study to assess the effectiveness of LM tools in SMEs operating in emerging countries, the following steps were completed.

Step 1. Selecting a company for the case study.

An Uzbek aluminium profile manufacturer is selected for the present case study analysis based on the country profile and size of industry. According to geographical areas and type of the industry, countries in Central Asia are classified as emerging ones. Also, the business at issue is the first specialized company to produce aluminium profiles and associated accessories in Uzbekistan. The company uses a full cycle of aluminium processing, from the casting of alloys of primary aluminium with the addition of alloy components constituted by previous scraps that are recycled, extrusion, colouring powder enamels, anodizing coating method, profile decorating with electric vacuum method, and machining of semi-finished pressed profiles. The case company is the second largest aluminium profile manufacturer in the country and its total number of employees is about 250 workers, including administrative and office staff.

Step 2. Creating the working team and developing the current map of the production processes.
In this stage, first the working team is created including two of the authors, plant managers, and shop floor operators of the company. Then, focused interviews are carried out with company experts to explore and map the current state of the production processes, with particular reference to organizational issues. Direct visual inspection is also performed to confirm the interview outcomes and uncover the potential wastes within the factory. Additionally, semi-structured interviews are conducted to define the most significant parameters of the manufacturing processes. Technological and management issues were detected by combining process mapping with the above-mentioned semi-structured interviews with the main process actors and managers of the company. Moreover, brainstorming is applied while defining the current state of production process together with its criticalities.

Step 3. Selecting key performance indicators (KPIs) and relevant Lean tools.
The relevant operational parameters of production processes are identified, together with the possible LM tools, based on the current literature. Additionally, based on the interviews and brainstorming two performance indicators are selected to compare the company's situation before and after LM application. The first KPI is process time of each operation, which supports both detecting wastes and then assessing the impact of LM tools implementation on reducing non-value-added time. Measuring this KPI can assist company managers to have a better perception of important data in each stage of the production process, such as transportation time, loading and unloading parts into machines, queuing and process time. The facility production capacity is selected as the second KPI in order to measure how LM techniques are able to affect the daily production rate. Moreover, the cumulated values of the daily production rate provide the total annual production volume of the company, which helps setting yearly strategic goals in an effective way (Ante, Facchini, Mossa, & Digiesi, 2018). In the next, appropriate LM tools are identified according to the available literature in this field. Table 1 shows the LM techniques that are selected for potential improvement and their associated aims (Harun, Habidin, & Latip, 2019; Ruiz et al., 2019).

Step 4. Implementation approach setting.
As the Figure 1 illustrates, three stages of conducting this case study are set after defining the parameters and suitable LM tools in the previous steps of the research methodology.

Table 1. Selected LM tools

Tool	Tool aim
VSM	To identify potential wastes and non-value-added activities and time in each phase of the production process
5W+1H	To define the root causes of the wastes identified through VSM and direct visual inspection. Supporting the proposal of solutions to minimize them
5S	To create sustainable implementation of LM by sorting, setting in order, shining, standardizing, and sustaining processes.
SOP	To smooth production processes through standardizing each task performed by both operators and machines.

In the first stage, the identification of potential wastes with their respective classification is carried out by direct visual observation, interviews, and brainstorming sessions based on the 7 waste categories (Ohno, 1998). In addition, non-value-added time has to be defined through process mapping. To this end, the VSM helps to represent the current state of a production process. In the second stage, the wastes previously defined are analysed by applying 5W+1H in order to determine their root causes and provide a possible elimination strategy. At last, 5S and SOP are utilized to reduce and eliminate the wastes as well as to provide sustainable implementation of LM tools. The VSM will again be useful to assess the improvements achieved with the Lean approach.

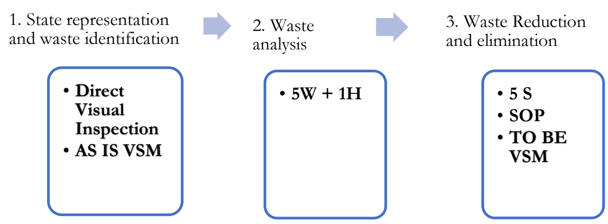

Figure 1. Stages of the implementation approach

4. Case study development

4.1. Current state process mapping

The case study setting is constituted by the Press Shop, the Painting Lines, and the Décor shop of the focus company, whose main functions are extruding aluminium profiles, delivering the chemical treatment, and painting profiles before labelling and packaging, as well as covering parts with a laminated pattern. Tables 2, 3, and 4 show the processes and activities performed in the above-mentioned departments associated with the type of the materials used in the operations.

Table 2. Press Shop activities

Activities/operations	Material
Transporting raw material from Raw Material Warehouse to furnaces	Aluminium billets 6 m long (Raw material)
Loading aluminium billets into furnaces	
Heating aluminium billets in the furnaces	
Cutting aluminium billets and loading them into presses	
Extruding billets to obtain profiles	Aluminium profiles (length 25.4 m)
Stretching aluminium profiles	
Cutting aluminium profiles, then locating them into baskets	
Delivering baskets to hardening and metal chip removing	Aluminium profiles (length 6 m)
Hardening and metal chip removal	
Delivering hardened profiles to chemical treatment	

Table 3. Painting line activities

Activities/operations	Materials
Profiles delivery to workstations	Aluminium profiles (length 6 m)
Unloading profiles from baskets and preparing for loading them on an overhead conveyor	
Loading on overhead conveyor and cleaning	
Painting	
Unloading painted profiles and delivering to either labelling or the Décor Shop	

Table 4. Décor Shop activities

Activities/operations	Material
Delivering painted profiles to workstations	Aluminium profiles (length 6 m)
Wrapping end sides of the painted profiles	
Covering raw materials with décor	
Loading raw materials into furnaces	
Furnace - laminating	
Unloading laminated parts from furnaces	
Part delivery to labelling	
Labelling	
Packaging	

4.2. Waste identification and analysis

The working team conducted the waste identification and classification processes. Table 5 represents the determined wastes that are classified based on the seven types of wastes – Muda suggested by Ohno (1998).

Table 5. Waste classification

Type	Identified waste
1. Transportation	1.1. Transporting raw materials from the warehouse to the Press Shop area in order to measure their weight before starting the production process. The warehouse is far away from the Press Shop
	1.2. Moving baskets around hardening to load materials into furnaces
	1.3. Long distance travelled for delivering aluminium profiles from the storage area of Décor shop to workstations
	1.4. Long distance moving of laminated profiles to labelling
2. Inventory	2.1. Storage area for defective parts is saturated
	2.2. Impossibility to store incoming painted profiles in the Décor shop's storage area due to not enough empty space available
	2.3. Not enough storage area to put the laminated profile packages in the outgoing material area of the Décor shop
3. Motion	3.1. Walking around the incoming material area of the Décor Shop searching for empty space to unload painted profiles
	3.2. Manual handling of laminated profiles to labelling
	3.3. Walking around to search pieces of equipment in the Décor Shop
4. Waiting	4.1. Waiting a too long time the press machines for extruding billets during tool change
	4.2. Waiting profiles in the stretching process
	4.3. Trucks have to wait for loading the laminated profiles and shipping them because of not complete parts
5. Defects	5.1. Incorrect set up of dies during tool change
	5.2. Defective profiles in painting
	5.3. Defective profiles in extruding
	5.4. Defective profiles in laminating
	5.5. Excess length of profiles in extruding
6. Over-processing	6.1. Multiple trials during dies change
	6.2. Repetitive profile surface cleaning before painting
7. Over-production	7.1. Extruding more profiles than what required by customers in the Press Shop
	7.2. Producing profiles without having an order (this affects 5 main profile codes)

In the next step, the 5W+1H tool is implemented to perform an extensive waste analysis and to define the root cause of each source of waste. Table 6 shows an example of outcomes.

Table 6. Example of 5W+1H analysis output

	Waste 4.1.
What:	Waiting the press machines for extruding billets during tool change
When:	When press dies are changed
Where:	Press Shop
Why:	New dies have to be tested during the tool change, and this takes a longer time. The press machines are quite old and previous poor maintenance activities by unskilled technicians caused the need for more extensive tests than what is usually necessary
Who:	Workers in the Press Shop
How:	In order to reduce the tool change time and utilize new dies, beforehand the press machines must be repaired completely, as well as a continuous integration with the die manufacturers is required.

4.3. Waste reduction and elimination

Once the existence of wastes and their potential sources are identified, the following step is defining possible improvement actions in order to either reduce or eliminate them. As it is mentioned in Section 3, the authors propose 5S and SOP as the most appropriate LM techniques because they can address the root causes of the non-value-added activities and prevent their reoccurrence.
The working team carried out an extensive identification of possible improvements through LM tools and collected them in tables for the activities in each department. As an example, Table 7 illustrates an extract from the table about Décor Shop processes.

Table 7. Example of 5S application in Décor Shop

Décor shop	
Sorting	Classify all the materials and tools; remove unnecessary and used items
Set in order	Arranging and labelling necessary tools for easy access (use)
Shining	Cleaning workplaces and machines regularly for safety and preventive maintenance
Standardizing	Defining each step of process and creating Operator Spreadsheet (OSS)
Sustaining	Providing training for the new procedures for continuous improvements

The activities that are included in the Sorting, Set in order, and Shining rows should be performed at first, while the other actions collected under the Standardizing and Sustaining categories should be carried out consequently in order to provide continuous improvements. The complete tables and dataset of improvement actions are available from the authors. Moreover, SOP sheets are created by the working team to standardize the production processes with the aim of supporting continuous improvement and production smoothing. As an example, the Operator's Spreadsheet (OSS) includes information about the description of each step of the operation instructions, process time, and necessary tools to complete each operation.

4.3.1. Re-layout of Décor Shop

As part of the improvement effort, the re-layout of Décor Shop is focused on the reduction of previously defined wastes such as the excess motion, inventory, and transportation within the department. Re-layout did not change the locations of the main machines such as laminating furnaces, whereas the position of support function areas, aisles, and secondary workstations was changed to reduce travel, effort, and time. Firstly, the painted profiles storage and the laminated final product temporary warehouse are re-allocated. Secondly, preparation areas were located closer to furnaces to avoid long transportation of profiles and operator's motion. Thirdly, the re-layout improved the issues associated with ergonomics and safety of workplaces. More layout details are not reported in the paper for space constraints but are available from the authors.

4.4. Evaluation of improvements

Two VSMs were developed in the present case study. The AS IS VSM, built in the first stage of the implementation approach, captures the current time required to complete Press Shop, Painting Line, and Décor Shop activities, whereas the TO BE VSM in the third stage computes the total time needed to perform each shop's processes after implementing the LM tools. Figure 2 and 3 shows the AS IS VSM and TO BE VSM outcomes as a percentage of non-value-added time in Décor Shop.

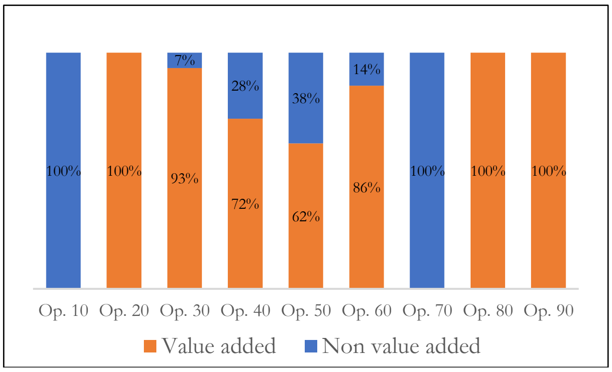

Figure 2. AS IS – VSM outcome

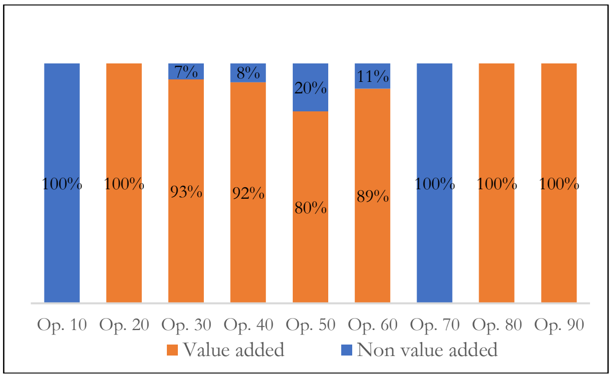

Figure 3. TO BE – VSM outcome

Based on the AS IS VSM the following non-value-added times were identified: loading into the puller and extruding in press (16%), painting profiles (18.5%), causing a total production rate equal to 23.5 t/day. The comparison of AS IS and TO BE VSMs is based on the numerical values of process and waiting time of each operation in Décor Shop before and after the LM application. VSMs do not include supply and delivery processes. The most outstanding outcome is associated with the 37%, 9.1%, and 3.4% reductions in processing time of Décor Shop, Press Shop, and Painting Line respectively. 5S and SOP application had a great impact on shortening the total process time (delivery to workstation, preparing for furnace, covering with décor, laminating, labelling, and packaging), from 56 min in the AS IS case to 41 min in the TO BE one. VSM and 5W+1H helped reducing changing and calibrating time of dies by 74% in the Press Shop.

In other words, the tool change time shortened from 175 min/day to 45 min/day. The stopping and cleaning time of the Painting Line was reduced by 63%. Moreover, the daily production rates of Press Shop, Painting Line, and Décor Shop were increased up to 30.1 t/day, 29.4 t/day and 30.0 t/day respectively.

5. Discussion and Conclusions

The application of LM tools to different industries has been extensively investigated, as well as companies of various types and sizes have adopted the Lean principles to reduce lead time, production costs and increase quality of final products. However, these studies have been limited in emerging countries, particularly SMEs in Central Asia (Bloom et al., 2012). In the present case study, the authors put forward an integrated approach relying on multiple LM tools for a Uzbek aluminium profiles manufacturer.

This case study has both academic and practical implications. First, it can stimulate further research about the application of Lean Manufacturing in emerging markets and the operational and economic benefits that its widespread adoption might bring to companies, not only SMEs but also large ones, with the ultimate aim of increasing their competitiveness worldwide. Based on the performed case study the application of LM tools in SMEs has nearly the same path as in large industries. However, the company profile in terms of where it locates and cultural behaviour of employees are significantly affected for successive implementation. So, the present study also fosters research devoted to understand the key contextual drivers of successful LM applications in Central Asia companies. Then, the developed approach provides researchers with insights on how to integrate different LM tools to exploit their mutual benefits. As such, it can inspire studies combining other Lean tools with the proposed ones in order to improve production processes. The case study represents practitioners, particularly those operating in emerging countries, how to actually apply the integration of LM tools for assessing and re-engineering production processes. It helps them to increase the internal time and cost efficiency of their businesses, which is a powerful lever to achieve higher levels of standards that might in turn support better export capabilities, leading to the opportunity to explore new international markets for their products. Finally, the proposed approach can assist other companies to achieve cost-effective, less time consuming, flexible, and more productive manufacturing through Lean Thinking. However, this work has a few limitations. Some proposals for improvement were not implemented because of limited time for the adjustment of the new procedures according to the LM tools application. Furthermore, the case study was performed in one SME of a Central Asia country, namely Uzbekistan, while additional case companies could be selected from other emerging countries and industries. An extended case study involving more companies may support to strengthen the knowledge about advantages and disadvantages of the current integration of LM tools.

Therefore, future research will be addressed to carry on the validation of the application of the proposed approach by applying it to multiple and various types of companies. This may help to confirm the results of the present case study.

Acknowledgements

The authors would like to thank the managers and the employees of the case company as well as Nabijonov Abdurakhim, Master of Science in Mechatronic Engineering at Politecnico di Torino, and Rakhimov Aziz, Bachelor Student in Mechanical Engineering at Turin Polytechnic University in Tashkent for their active involvement in the research.

References

Abhishek, P. G., & Pratap, M. (2020). Achieving Lean Warehousing Through Value Stream Mapping. *South Asian Journal of Business and Management Cases*. https://doi.org/10.1177/2277977920958551

Ante, G., Facchini, F., Mossa, G., & Digiesi, S. (2018). Developing a key performance indicators tree for lean and smart production systems. *IFAC-PapersOnLine*, *51*(11), 13–18. https://doi.org/10.1016/j.ifacol.2018.08.227

Antony, J. (2011). Six Sigma vs Lean: Some perspectives from leading academics and practitioners. *International Journal of Productivity and Performance Management*, *60*(2), 185–190. https://doi.org/10.1108/17410401111101494

Baby, B., Prasanth, N., & Jebadurai, S. S. (2018). Implementation of lean principles to improve the operations of a sales warehouse in the manufacturing industry. *International Journal of Technology*, *9*(1), 46–54. https://doi.org/10.14716/ijtech.v9i1.1161

Bloom, N., Schweiger, H., & Van Reenen, J. (2012). The land that lean manufacturing forgot?: Management practices in transition countries bloom et al. The land that lean manufacturing forgot? *Economics of Transition*, *20*(4), 593–635. https://doi.org/10.1111/j.1468-0351.2012.00444.x

Bonavia, T. and Marin, J. A. (2006). An empirical study of lean production in the ceramic tile industry in Spain. *International Journal of Operations & Production Management*, *26*(5), 505–631.

Bonilla-Ramirez, K. A., Marcos-Palacios, P., Quiroz-

Flores, J. C., Ramos-Palomino, E. D., & Alvarez-Merino, J. C. (2019). Implementation of Lean Warehousing to Reduce the Level of Returns in a Distribution Company. *IEEE International Conference on Industrial Engineering and Engineering Management*, (December), 886–890. https://doi.org/10.1109/IEEM44572.2019.8978755

Cagliano, A. C., Grimaldi, S., & Schenone, M. (2018). Proposing a new framework for lean warehousing: First experimental validations. *Proceedings of the Summer School Francesco Turco*, *2018-Septe*, 156–163.

De Carlo, F., Arleo, M. A., Borgia, O., & Tucci, M. (2013). Layout design for a low capacity manufacturing line: A case study. *International Journal of Engineering Business Management*, *5*(SPL.ISSUE), 1–10. https://doi.org/10.5772/56883

Dotoli, M., Epicoco, N., Falagario, M., & Costantino, N. (2013). A lean warehousing integrated approach: A case study. *IEEE International Conference on Emerging Technologies and Factory Automation, ETFA*, *20*(April 2015). https://doi.org/10.1109/ETFA.2013.6648030

Dotoli, M., Epicoco, N., Falagario, M., Costantino, N., & Turchiano, B. (2015). An integrated approach for warehouse analysis and optimization: A case study. *Computers in Industry*, *70*(1), 56–69. https://doi.org/10.1016/j.compind.2014.12.004

Elkhairi, A., Fedouaki, F., & El Alami, S. (2019). Barriers and critical success factors for implementing lean manufacturing in SMEs. *IFAC-PapersOnLine*, *52*(13), 565–570. https://doi.org/10.1016/j.ifacol.2019.11.303

Gebauer, H., Kickuth, M. and Friedli, F. (2009). Lean management practices in the pharmaceutical industry. *International Journal of Services & Operations Management*, *5*(4), 463–481.

Harun, M. F., Habidin, N. F., & Latip, N. A. M. (2019). 5S lean tool, value stream mapping and warehouse performance: Conceptual framework. *International Journal of Supply Chain Management*, *8*(3), 605–608.

Kovács, G. (2020). Combination of Lean value-oriented conception and facility layout design for even more significant efficiency improvement and cost reduction. *International Journal of Production Research*, *58*(10), 2916–2936. https://doi.org/10.1080/00207543.2020.1712490

Moriones, A.B., Pintado, A.B. and Cerio, J. M. (2008). The role of organizational context and infrastructure practices in JIT implementation. *International Journal of Operations & Production Management*, *28*(11), 1042–1066.

Ohno, T. (1998). *Toyota Production System: Beyond Large-Scale Production*. New York: Productivity Press.

Panizzolo, R., Garengo, P., Sharma, M. K., & Gore, A. (2012). Lean manufacturing in developing countries: Evidence from Indian SMEs. *Production Planning and Control*, *23*(10–11), 769–788. https://doi.org/10.1080/09537287.2011.642155

Panwar, A., Jain, R., & Rathore, A. P. S. (2015). Lean implementation in Indian process industries - Some empirical evidence. In *Journal of Manufacturing Technology Management* (Vol. 26). https://doi.org/10.1108/JMTM-05-2013-0049

Pearce, A., Pons, D., & Neitzert, T. (2018). Implementing lean—Outcomes from SME case studies. *Operations Research Perspectives*, *5*, 94–104. https://doi.org/10.1016/j.orp.2018.02.002

Pinto, G. F. L., Silva, F. J. G., Campilho, R. D. S. G., Casais, R. B., Fernandes, A. J., & Baptista, A. (2019). Continuous improvement in maintenance: A case study in the automotive industry involving Lean tools. *Procedia Manufacturing*, *38*(2019), 1582–1591. https://doi.org/10.1016/j.promfg.2020.01.127

Putri, N. T., & Dona, L. S. (2019). Application of lean manufacturing concept for redesigning facilities layout in Indonesian home-food industry: A case study. *TQM Journal*, *31*(5), 815–830. https://doi.org/10.1108/TQM-02-2019-0033

https://doi.org/10.1016/j.proeng.2012.07.375

Ruiz, S., Simón, A., Sotelo, F., & Raymundo, C. (2019). Optimized plant distribution and 5S model that allows SMEs to increase productivity in textiles. *Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology*, *2019-July*(July), 24–26. https://doi.org/10.18687/LACCEI2019.1.1.59

Shah, R. and Ward, P. T. (2003). Lean manufacturing: context, practices bundles, and performance. *Journal of Operations Management*, *21*(2), 129–149.

Sohal, A.S. and Egglestone, A. (1994). Lean production: experience among Australian organizations. *International Journal of Operations & Production Management, 14*(11), 35–51.

Sohal, A. S. (1996). Developing a lean production organization: An Australian case study. *International Journal of Operations and Production Management*, *16*(2), 91–102. https://doi.org/10.1108/01443579610109866

Womack, J., Jones, D. T., & Roos, D. (1990). *The machine that changed the world: the triumph of lean production*. New York:Rawson Macmillan.

Yamazaki, Y., Shigematsu, K., Kato, S., Kojima, F., Onari, H., & Takata, S. (2017). Design method of material handling systems for lean automation—Integrating equipment for reducing wasted waiting time. *CIRP Annals - Manufacturing Technology*, *66*(1), 449–452. https://doi.org/10.1016/j.cirp.2017.04.011

Zhou, B. (2016). Lean principles, practices, and impacts: a study on small and medium-sized enterprises (SMEs). *Annals of Operations Research*, *241*(1–2), 457–474. https://doi.org/10.1007/s10479-012-1177-3