PRODUCTION & MANUFACTURING | RESEARCH ARTICLE

Production lead time improvement through lean manufacturing

Sisay G. Gebeeyehu¹, Muluken Abebe* and Amdewok Gochel

Abstract: Lean manufacturing (LM) practices and tools have played vital role in several manufacturing industries to enhance the competitive edge in in the global market. The purpose of this paper is to use the lean principles, practice and tools in Hibret Manufacturing & Machine Building Industries (HMMBI) in Ethiopia. The existence of high production lead time is getting the basic problem for HMIBI that is why this research gives more attention. The study aims to improve the production lead time by minimizing non-value adding activities associated with several resources in the process. Both qualitative and quantitative data collection methods are used. The process time and floor layout are studied and mapped using Value Stream Mapping, and Spaghetti Diagram to identify wastes. The result shows that production lead time, work in process (WIP), non-value adding time (waiting time) and total distance traveled are reduced by 23.66%, 8.6%, 37.74%, 61.2% respectively. Finally, the process cycle efficiency is improved by 25.59%. The study is found significant for Hibret Manufacturing & Machine Building Industries (HMMBI) and for similar manufacturing industries.

Subjects: Manufacturing Engineering; Manufacturing Engineering; Engineering Productivity

Keywords: Lead time; lean manufacturing; value stream map

1. Introduction

The Toyota Motor Company’s Eiji Toyoda, Taiichi Ohno, and Shingeo Shingo established a discipline that focused on process production system known as “Toyota Production System” (James et al., 1990). The purpose of the Toyota Production System is to reduce the consumption of resources that added no value to the desired service or product. Hence, Japanese business uses lean...
manufacturing techniques to improve human effort, materials and throughput time in the entire process (Kulkarni, P. (2014)).

The lean manufacturing concept was popularized in American industries in large. The concept was accredited by the Massachusetts Institute of Technology. The study was focused on the movement of mass production towards production as described in “The Machine that Changed the World” (Womack & Jones, 1997), so that significant performance gap was identified in Western and Japanese automotive industries. The book described the important elements of superior performance metrics as a lean production.

Lean is the integration of principles, practices, tools, and techniques to eliminate non-value-added activities. The elimination of those activities can improve both the cycle time and production lead time as Čiariené and Vienažiūnienė (2015) and Prajapati and Vivek (2015) reviewed in the previous research works. The use of lean practice has been getting a special attention in several manufacturing industries to exceed the customers’ expectations by enhancing product’s quality, reducing production lead time, and minimizing costs (Čiariené & Vienažiūnienė, 2015). Despite a high number of related research works via lean concept in different developed countries, the application of this science needs more empirical research works in Ethiopia. Ethiopia, in Africa, is a developing country that has been establishing the manufacturing industries in large. However, some local industries are not applying lean manufacturing practice whatsoever it gets high production lead time.

Hibret Manufacturing & Machine Building Industries (HMMBI) is a local machine building industry taken into account as case. The study aims to signify the implication of lean practice in local industries so that similar manufacturing sectors can use its contribution. The case study begins with the analysis of lean concept in a several research works. Previous but related literatures are reviewed and the methodology adopted in several empirical research is also considered.

2. Literature review
Improving the production lead time, in manufacturing companies, is an essential operation for accomplishing the desired product with affordable cost and quality. After the Second World War, Japanese manufacturers were facing resource and financial crises. But they established a discipline that was focused on production system, known as Toyota Production System. Lean manufacturing system was employed to reduce resource consumption that does not add any value on final product since lean practice is capable to improve human effort, materials utilization and time taking (James et al., 1990). The fundamental concept of lean manufacturing is to provide a quality product while also ensuring that the product does not cost too much to the customer (Gupta & Kumar Jain, 2013, Tiwari, 2019).

Lean system is concerned on minimizing wastes and enhancing production lead time so that it has been implemented in different manufacturing industries. For example, it is used to improve the process efficiency and productivity of metal production and a great deal of improvements have been achieved (Chauhan et al., 2015; Sérgio & Borges Lopes, 2019). However, some local industries in Ethiopia were not applying lean manufacturing system whatsoever it gets high production lead time. HMMBI is a local machine building industry taken as case study for this study to improve the production lead time.

2.1. Principles and concepts of lean practice
As Womack and Jones (1997) stated, the study has put-on a “profound effect on manufacturing executives in general, and not just those in the automobile industry”. The study that dealt about lean concept was focused on the elimination of waste, muda in Japanese line with Ohno’s Toyota Production System. The lean production is basically followed five stages or principles to maximize the output by minimizing the waste (Womack & Jones, 1997) and as referred by Seyed Mojib Zahraee (2020). The principles are:
Define the value (Specify value)
Map the value stream (Identify the value stream)
Smooth process flow
Establish pull (Production based on pull) and
Perfection (elimination of waste with continuous improvement)

Figure 1 has attempted to show these principles (Womack & Jones, 1997) and its aim in the case production process.

The lean principles and tools have been increasingly employed in different manufacturing and construction industries across several sectors, with numerous successful implementations both inside and outside production environments (Nallusamy & Kumar, 2018; Sérgio & Borges Lopes, 2019; Tiwari & Kumar Tiwari, 2019; Dineshkumar, B., & Dhivyamenaga, T. (2016). According to Monir and Kamal (2015), lean enterprise institute introduced five principles to implement lean manufacturing system as shown in Figure 1. Companies following lean manufacturing have better flexibility to produce an operational and cultural environment that is highly conducive to waste minimization as Gupta and Kumar Jain (2013) reviewed related literatures.

When lean system is applied in manufacturing process, scholars should look through one important point “what is called lean waste”. Waste is any activity in process that consumes resources without adding value to the final product. Value, quantity, time and movement are some metrics in which waste can be depicted. Over production, unnecessary inventory, defects or rejection, unnecessary transport, waiting, over processing and unnecessary motion is the seven well known wastes (Pakdil & Leonard, 2014). Therefore, minimizing this waste need individual attention so as to achieve the desired production lead time.

Most of the previous research works show the different approach in reducing manufacturing or production lead time by using only lean manufacturing principles or/and lean manufacturing tools. Several researchers tried to introduce the lean manufacturing tools application and benefits for production lead time reduction (Rad, M., 2008). However, integrated lean manufacturing system and manufacturing performance indicators has a great advantage for quantifying and controlling
the manufacturing waste as well as reduced production lead time with the help of value stream map.

2.1.1. Value stream map (VSM)
As stated in the above section, the aim of this study is improving the production lead time. Hence, this research gives a special attention for value stream map. Value stream is an activity required to design and order exact products from concept development until launching, from order received to delivery time including all process steps raw material, process and storage.

Some examples of muda in the production system are waiting of machine and peoples in their actions (Thangarajoo & Smith, 2015; Fawaz, A., et al. 2007; Rauniyar, M. 2007). It addresses all flow of process, material and information. Map all of the steps of value-added and non-value-added activities. VSM has taking several variations to identify the value stream of service and product and also minimize non-value adding waste beside the value stream.

After specifying the value by the customer’s lean step is used to identify the value-added process or products. Business activities in the value stream mapping for a product has three categories that should be well-defined within the company as Seyed Mojib Zahraee (2020) discussed. These are value adding activity, non-value adding activity and non-value adding activity but necessary.

- Value Adding Activity:—Activities and actions that add value in the customer and the customer make a product or service more valuable and would be happy to pay for it.
- Non-Value Adding Activity (Type One Muda):—it is pure waste and those activities customer; do not happy to pay for it. These activities are clearly “wastes” and it is immediately avoidable or minimized.
- Necessary Non-value Adding Activity (Type Two Muda):—those activities or actions do not add value but necessary. The customer does not pay for a product or service more valuable but are necessary, in the result the current supply process is radically changed. This type of waste is more challenging to eliminate or minimized in the short period of time. Generally, the VSM is stated and briefed in the methodology section.

3. Materials and methods

3.1. Case study approach
The study demonstrates the application of lean manufacturing system in Hibret Manufacturing and Machine Building Industry (HMMBI) to improve the production lead time. Initially, the current production system (i.e., HMMBI) has 10 workstations, 36 operators and 5 machines, it is mentioned in the results and discussion section. The lean manufacturing tool and approaches are also used. The data area collected in the entire production system (existing system) by taking the production layouts, waste, value adding, none value adding activities and time study.

Both qualitative and quantitative data collection techniques are used in the case study. In quantitative data, the numerical values are measured, collected and analyzed from shop floor. The existing layout of the work station is drawn using value stream map. The movement of the materials and workers is also shown using spaghetti model. To get some qualitative insight group discussions, expert panels, in depth interviews with managers and production supervisors are conducted. The qualitative data is focused on the bottleneck area.

3.1.1. Product matrix
The group of finished parts (product) that share common production process and machines are categorized. Table 1 shows the product matrix of Hibret Manufacturing and Machine Building
| Product Family One       | Material Preparation | CNC Lathe | CNC Milling | Conventional Milling | Gear Hobbing | Heat Treatment | Grinding | Quality Inspection | Assembling |
|--------------------------|----------------------|-----------|-------------|----------------------|--------------|----------------|----------|--------------------|------------|
| Spline Shaft             | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Input Shaft              | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Output Shaft             | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Neck Plat Shaft          | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Product Family Two       |                      |           |             |                      |              |                |          |                    |            |
| Spur Gear                | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Helical Gear             | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Bevel Gear               | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Worm Gear                | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Product Family Three     |                      |           |             |                      |              |                |          |                    |            |
| Dies                     | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |
| Molds                    | x                    | x         | x           | x                    | x            | x              | x        | x                  | x          |

x— defines products

Table 1. Product matrix (Family) of Hibret manufacturing and machine building industry in the entire production system (Source: this author)
Industry. Based on the collected fact, the researcher is focused on parts with continuous customer demand. So, the output shaft and spur gear are taken into account.

3.1.2. Data collection method
In the primary data preparation and production time, inspection time, transfer time and waiting time are collected. Historical document that illustrated the production achievement of the case company, machine manuals, and related literatures are used for secondary data.

3.2. Value stream mapping (VSM)
Value stream mapping is used to record a time used for value added, non-value added, cycle time and changeover time as previous research works reached on Gunji Venkata Punna Rao (2017) Ramesh (2008) Venkataraman et al. (2014). To demonstrate the value stream mapping, the following steps are applied.

1. Kaizen Principle (Go To Gemba and Check Gembustu): the production process is observed, understood, chosen and confirmed to identify demand, process flow, material flow and information flow.
2. Selection of Product Matrix
3. Map VSM for Existing the System: the process line is drawn by using Minitab Quality Companion statistical tool considering customer demand, quality for conformance and lead time. The customer icon pictured in the upper right-hand side of a map, the supplier icon also pictured in the upper left-hand side of the map so that the takt time and cycle time is calculated. The time line shows VA, NVA, NNVA and WIP time.
4. Map Category: The customer demand, available time per shift, shift per day, break time per shift, available time in a day, a week, a month are fulfilled so as to determine the takt time.
5. Process Category: Each work station is categorized with its cycle time, value adding time, non-value adding time, changeover time, and operators.
6. Inventory Category: all selected work stations and its buffers stock are looked carefully
7. Future State Map:—The value stream map answers following five questions (Alireza et al., 2011).

(a) What is the takt time for the selected product family?
(b) Will the production produce to finished products supermarket or direct shipping?
(c) Where can continuous production process flow be implemented?
(d) Where is a need for a supermarket pull system within the value stream?
(e) What process improvements will be necessary?

To develop future value stream map, the takt time is computed as:

\[
\text{Takt Time} = \frac{\text{Available Time}}{\text{Customer Demand}}
\]

Suggestion for Improvement: The developed future VSM enable to shows the production process clearly. Figure 2 shows a generic pattern how the VSM was carried out in HMMBI process.

3.3. Direct observation for time study
Time and motion study is considered to standardize the process time and its performance. Stop watch is used to record an accurate time processing time. While recording the time, the following basic steps are customized (Kitaw, 2009–24).

1. Selection of Task (Process Line & Product)
(2) Standardize and Divided the Method of Working for Machine

(3) Decide the Number of Cycle Time: The following equation is used to get the required standard time by taking confidence interval as 95% to find out the appropriate sample size (\(\bar{x}\) and). The equation is further used to determine the required number of observations or cycle times (D.C. Montgomery, 2009).

\[
\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_2 + x_3 + \ldots + x_n}{n} \tag{1}
\]

Where: \(\bar{x}\) = sample mean
\(n\) = no of observation,
\(x_i\) = observation, \(i = 1, 2 \ldots \ldots n\)

\[
\delta = \sqrt{\frac{\sum_{i=1}^{n-1} (x_i - \bar{x})^2}{n-1}} \tag{2}
\]

Where \(\delta\) = standard deviation of sample
\(n\) = no of observation,
\(x_i\) = observed value
\(\bar{x}\) = sample mean
\[ n > \frac{(Z\delta)^2}{(hX)^2} \]  

(3)

Where \( n \) = number of observations

\( Z \) = standard normal deviation for the desired confidence level (1 = 68%, 1.96 = 95% & 3 = 99%).

\( \delta \) = Standard deviation of sample

\( X \) = Mean of initial preliminary sample,

\( h \) = The precision interval in percent (\( h = \pm 5\% \), then \( h = 0.05 \))

(1) Determine Performance Rating and Normal Time: The normal time is the worker takes when working at normal step and it is calculated as:

\[ \text{Normal Time (NT)} = \frac{\text{observed time (OT) } \times \text{performance Rating (PR)}}{\text{Normal Time}} \]

The performance Rating (PR) is usually taken as 100% (Naresh, 2011)

(1) Determine the Allowance (fatigue, toilet, breakfast and relaxation allowances)

(2) Determine the Standard Time: The standard time is the sum of Normal time and its Allowances. The allowances can be taken from 12% to 18% ((Naresh, 2011; and Kitaw, 2009)). Therefore, it is calculated as:

\[ \text{Standard Time} = \frac{\text{Normal Time}}{1 - \text{Allowance factor (PDF)}} \]  

(4)

3.4. Plant layout and line balancing

The existing production layout is taken into account to improve the production lead time. The work load is also examined to record the idle time in each workstation. The spaghetti model is used to measure and analyze the production layout. The cycle time and number of work stations are critically examined.

3.4.1. Spaghetti diagram

A spaghetti diagram is a graphic representation showing a continuous movement working process. These tools place a process on paper drawing lines to show the process steps, material flow and information. Since the lean manufacturing practice has been used in several industries (S.M. Zahraee, 2015), spaghetti diagram is used to identify the poor laid-out works in the entire process (Katarina et al., 2017).

3.5. Techniques and tools

The following statistical software are used accordingly.

Sigma XL: The tool is integrated with Microsoft Excel to calculate the takt time, value added, non-value added and BNVA activities. The current and future value stream map is drawn and looked through to examine performance metrics (activities).

Minitab Quality Companion: The Quality Companion is used to calculate the total lead time, the cycle time, value added cycle, non-value-added cycle, process cycle efficiency (Hossain, M., 2014), WIP, total distance and takt time.
Edarw Max: It is used to draw flowcharts, network diagram and to construct value stream mapping.

4. Result and discussion
At 95% confidence level, five-time observations are taken as shown in Table 2. All possible value adding, non-value adding, necessary non-value adding activities and the travel distance for material and manpower is measured when shaft and spur gear were manufactured.

Having arranged and grouped each workstation, VSM is developed using both Quality Companion and SigmaXL statistical software. The SigmaXL helped to analyze the future value stream map for value adding, non-value adding and necessary non-value adding activities whereas Quality Companion is used to calculate lead time, WIP time, takt time, cycle time, value adding cycle time, non-value adding cycle time and total travel distances as shown in Figure 5.

The existence of backtrack was one problem for production lead time, especially in conventional milling and quality inspection operations. Hence, workstations are grouped together based on activity relationship, as shown in Figure 4, developed with EdrawMax. In accordance with takt time, the total time of value Adding (VA), Non-Value Adding (NVA) and Necessarily Non-Value Adding (NNVA) are recorded in the existing production process. The takt time used for producing one unit product is found as 20 hours which implies the customer receives it within this time span (i.e., the production time is 300 hrs./month and demand is 15 product/month) as illustrated in the methodology section. Based on the investigation, the total time of each activity is calculated and proportion is made. As shown in Figure 3, VA contributed the smallest proportion and as a result it needs improvement.

For reducing the production lead time, process efficiency, cycle time, production rate, machine uptime and over all equipment effectiveness are taken into account as key performance indicators. In the case study, conventional milling, heat treatment and gear hobbing operations possessed high waiting time. Not only this, but the distance to travel the material was also found significant, which was 1553 m. Hence, the layout was re-designed based on line balancing technique so as to reduce backtracking and waiting time as shown in Figure 5.

| No | Description (Activities)       | Quantity | People | Distance In Meter | Time In Hour | Activities Type in Hour |
|----|--------------------------------|----------|--------|-------------------|--------------|-------------------------|
|    |                                |          |        |                   |              | VA         | NVA | NNVA |
| 1  | Preparation                    | 01       | 01     | 207 m             | 16.263       | 0.18        | 16.083 | 0    |
| 2  | CNC Lathe                      | 01       | 01     | 3 m               | 24.8767      | 11.21       | 12.416 | 1.25 |
| 3  | CNC Milling Operation          | 01       | 01     | 3 m               | 11.02        | 0.77        | 8     | 2.25 |
| 4  | Conventional milling           | 01       | 02     | 3 m               | 25.8333      | 25.00       | 0.3333 | 0.5  |
| 5  | Gear Hobbing operation         | 01       | 02     | 80 m              | 34.3333      | 16.00       | 8.333  | 10   |
| 6  | Heat Treatment                 | 01       | 14     | 45 m              | 26.22        | 1.97        | 20.25  | 4    |
| 7  | Grinding Operation             | 01       | 01     | 20 m              | 11.933       | 3.60        | 8     | 0.333|
| 8  | Quality inspection             | 01       | 04     | 241 m             | 2.6663       | 0.00        | 0.333  | 2.333|
| 9  | Assembling and storage         | 01       | 01     | 9.403             | 9.403        | 0.07        | 9.333  | 0    |
|    | Total                          |          | 27     | 60m               | 162.549      | 58.80       | 83.08  | 20.67 |

Table 2. Summary of VA time, NVA time and NNVA time in the production line for, collected to develop the future VSM
Figure 3. Proportion of VA, NVA and BNVA time.

- NVA Time 63%
- Value-Add Time 27%
- BNVA Time 10%

Figure 4. The floor of workstations grouped together based on activity relationship, developed with EdrawMax.

Figure 5. Proposed value stream map that represents the future process, constructed based on the collected facts in Table 2.
Production system improvement and formulation of future value stream map is developed for the selected process. It involves a set of activities including the resources, manpower, materials, space allocation, and meeting the stated objectives. In this regard a comprehensive development plan for better process flow (spaghetti), balancing the work content in the production work station, develop the frame work for production lead time improvement by integrating the manufacturing performance indicators and lean manufacturing systems are reached on. And finally, a proposed value stream map is developed and analyzed as shown in Figure 5. The improved system (future VSM) is developed by combining similar operations, applying process quality assurance, line balancing and improving the plant layout.

4.1. Major findings and its contribution
The total cycle time to manufacture a unit product (one machine assembly) is found 79.47 hours; VA cycle time is 58.80 hours and NNVA/BNVA cycle time is 20.67 hours. The production lead time is then reduced from 212.91 to 162.647 hours. This improvement is achieved after grouping similar operations through line balance and applying process quality. The WIP time also reduced from 196.83 to 146.46 hours, the non-value adding cycle time is reduced from 133.45 to 83.08 hours; total distance

**Figure 6. Comparison of work station (first figure), Comparison of operators or workers (middle figure), and Processing Time (third figure) before and after improvement.**
moved both for material and operator is reduced from 1,553 to 602 meter. Besides to this, the numbers of workstations are reduced to 9 and backtracking is eliminated so that the production line is improved by 36.2%. Figure 6 shows the improvements achieved in the case study. The first figure illustrates the existed and the improved number of work stations, the middle figure presents the dynamic reduction of operators (workers) in number and the third figure illustrate the improved processing time interims of process cycle efficiency (PCE), WIP time, NVA time and the distance traveled so that production lead time is improved.

5. Conclusion
This paper identified a set of critical issues affecting the production lead time of the case study. By integrating lean manufacturing system and manufacturing performance indicators, the research work improved the production lead time by 50.361 hours, WIP time reduced from 196.83 to 146.46 hours, waiting time was also reduced from 133.45 hours to 83.08 hours. As a result, process cycle efficiency has been also improved by 8.6%. The process also enables to reduce the number of operators from 36 to 27 in a single shift. Moreover, the total travelled distance is reduced from 1553 to 602 meters. Hence, all the above indicators show that employing lean manufacturing practice is vital to enhance performance metrics. It can also be further concluded that this investigation can be applied for similar manufacturing setups as a means of productivity improvement by reducing the production lead time.

Funding
The authors received no direct funding for this research.

Author details
Sisay G. Gebeyehu1
Mulukzen Abebe
E-mail: mulukzena334@gmail.com
Amdework Gochel
1 Industrial Engineering Department*, Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Citation information
Cite this article as: Production lead time improvement through lean manufacturing. Sisay G. Gebeyehu, Mulukzen Abebe & Amdework Gochel, Cogent Engineering (2022), 9: 2034255.

References
Alikeza E. et al. (2011). Application of value stream mapping using simulation to decrease production lead time a Malaysian manufacturing case. Int. J. Industrial and Systems Engineering, 230-250 (8).
Chauhan, N. D., Dr. M. N. Qureshi, Dr. T. N. Desai, and R. B. Dave, et al. (2019). An applications of lean manufacturing principles, tools and techniques in industry. Proceeding of the National Conference on – Recent Advances in CAD/ CAM/CAE (pp. 1–11), Vadodara City: ResearchGate. 
Čapiné, R., & Vienžindienė, M. (2015). An empirical study of lean concept manifestation. 11th International Strategic Management Conference 2015 (pp. 225–233). Elsevier.
Dineshkumar, B., & Dhiviyamenaga, T. (2016). Study on lean principle application in construction industries. Indian Journal of Science and Technology, 1-5(9). doi:10.17485/ijst/2016/v9i2/86366.
Douglas C. Montgomery. (2009). Introduction to Statistical Quality Control: United States of America: Don Fowley Fowers A. Abdulmalek and Jayant Rajgopal, et al. (2007). Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study international journal of production economy. ScienteDirect: International Journal of Production Economics 107 , 223–236 https://www.sciencedirect.com/science/article/pii/S0925527306002258.
Gurji Venkata Punna Rao, S. N. (2017). augmentation of production level using different lean approaches in medium scale manufacturing industries. International Journal of Mechanical Engineering and Technology (IJMET) 8 , 360–372. https://ieeexplore.ieee.org/doi/10.1109/VOLUME_8_ISSUE_12/IJMET_08_12_036.pdf.
Gupta, S., & Kumar Jain, S. (2013). A literature review of lean manufacturing. International Journal of Management Science and Engineering Management, 8(4), 241–249. https://doi.org/10.1080/17509653.2013.825074.
Hossain, M. (2014). An approach to reduce the manufacturing waste & improve the process cycle efficiency. ib.buet.ac.bd.
James Womack, Dan Jones and Daniel Roos, et al. (1990). The machine that changed the world. Macmillan Publishing Company. www.lean.org.
Kashar M. Mani N., Rohan S., Delfin A. and Yulfo G., et al. (2018). Application of lean manufacturing principles in optimizing factory production. In New Jersey’s Governor’s school of engineering and technology. seorutgers.edu 1–8.
Kulkarni, P. (2014). Productivity improvement through lean deployment & work study methods. IJRET: International Journal of Research in Engineering and Technology 03 , 429–434. https://citeeseerx.ist.psu.edu/viewdoc/download?doi=10.11.676.2759&rep=rep1&type=pdf.
Monir, M., & Kamal, M. (2015). A case study to reduce the manufacturing waste prior to improve the productivity factors of a Litchi Juice production plant by using value stream map and six sigma scale. International Journal of Scientific & Engineering Research 6 , 1895–1905 https://www.ijser.org/researchpaper/A-Case-Study-to-Reduce-the-Manufacturing-Waste-Prior-to-Improve-the-Productivity-Factors-of-a-Litchi-Juice-Production.pdf.
Nallusamy, S., & Kumar, V. (2018). implementation of total productive maintenance to enhance the overall equipment effectiveness in medium scale
industries. *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)*, 8(1), 1027–1038. https://doi.org/10.24247/ijmperdfeb2018123

Naresh, Paneru (2011). Implementation of lean manufacturing tool in garment manufacturing process focusing sewing section of men’s shirt, Oulu University of Applied science.

Pakdil, F., & Leonard, M. (2014). Criteria for a lean organisation: Development of a lean assessment tool. *International Journal of Production Research, 52*(15), 4587–4607. https://doi.org/10.1080/00207543.2013.879614

Prajapati, M. R., & Vivek, A. D. (2015). Cycle time reduction using lean principles and techniques: A review. *International Journal of Advance Industrial Engineering* 3 208–2013. https://www.researchgate.net/publication/296456225

Ramesh, K. S. (2008). Implementation of a lean model for carrying out value stream mapping in a manufacturing industry. *Journal of Industrial and Systems Engineering* 3, 180–196. http://www.jise.ir/article_19

Raunig, M., & Tiwari, K. R., & Kumar Tiwari, J. (2019). Identification of key lean practices within Indian automotive SMEs environment. *International Journal of Industrial and Systems Engineering, 33*(1), 17–37. https://doi.org/10.1504/IJISE.2019.102040

Venkataraman, K., Ramnath B., Kumar V., and Elanchezhiand C., et al. (2014). Application of value stream mapping for reduction of cycle time in a machining process. ICMPC.

Womack, J. P., & Jones, D. T. (1997). Lean thinking—banish waste and create wealth in your corporation. In E. B. Wilson (Ed.), *Journal of the operational research society* 398.

Zahraee, S. M. (2015). A survey on lean manufacturing implementation in a selected manufacturing industry in Iran. *International Journal of Lean Six Sigma* 11, 136–148 https://www.researchgate.net/publication/301554102_A_survey_on_Lean_Manufacturing_implementation_in_a_selected_manufacturing_industry_in_Iran.
