International Journal of Production Management and Engineering

https://doi.org/10.4995/ijpme.2021.14561
Received: 2020-11-03 Accepted: 2021-07-24

Lean Six Sigma Implementation, A Systematic Literature Review

Tampubolon, S.[a1*], Purba, H.H.[a2]

[a] Industrial Engineering Department, Mercu Buana University, Jln. Meruya Selatan No 1, Kembangan, Jakarta 11650, Indonesia.

[a1] *nomlas26@yahoo.com*, [a2] *humiras.hardi@mercubuana.ac.id*

Abstract: Organizations must be able to meet customer needs in today's complex market situation and business environment, the needs and essentials for their satisfaction such as high product quality, competitive costs and faster delivery. Organization need to apply a comprehensive concept and method on managing this requirement. This systematic review intends to identify how Lean Six sigma implementation in many industries. Lean Six Sigma (LSS) is a method that has been widely used in research in various fields and continues to grow, to get the most common solution it is necessary to review the method. This research is to observe concept and method still relevant to be use and effectively improved the business performance and customer satisfaction. For the identity of the LSS Papers, a total of 50 research papers were reviewed which met the criteria, Research object, country of research and year of publication and Result of research. The result show that LSS is still being used and successfuly help the organization to improve their competitiveness, improve quality, reduce costs, increase customer satisfaction, increase productivity, and increase employee morale.

Key words: lean manufacturing, DMAIC, Lean-Six Sigma, Six-Sigma, VSM.

1. Introduction

All sectors open to global competition have equal opportunities from various organizations around the world. In an effort to respond to the pressure created by global competition from all sectors, opportunities for organizations from different parts of the world have equal opportunities in global competition so that companies have to adopt competitive and innovative methods, which in most cases, tend to emphasize quality and focus on customers. Apart from focusing on improving quality, products, services and processes, most of these approaches also focus on customer satisfaction. The use of quality methods is increasing.

Lean manufacturing technique is a concept adopted to eliminate waste and processes that do not add any value to customer satisfaction. It also aims to increase the efficiency and effectiveness of the company. Meanwhile, the six-sigma method is needed to reduce process variability. Motorola was one of the companies that was successful in adopting the Six-sigma method in the 1980s, in an effort to increase the level of quality by reducing variability in manufacturing operations in a continuous and consistent manner (Olanrewaju et al., 2019).

Six-gima dedicates what customers want from a product of the highest quality. On the other hand, lean manufacturing in particular is focused on reducing waste and non-adding value for customer satisfaction.

Now Lean Six Sigma (LSS) has become a leading business improvement methodology that has been successfully implemented since being implemented in all types of businesses. The goal of LSS is to Drive

To cite this article: Tampubolon, S., Purba, H.H. (2021). Lean Six Sigma Implementation, A Systematic Literature Review. *International Journal of Production Management and Engineering*, *9*(2), 125-139. https://doi.org/10.4995/ijpme.2021.14561

business improvement with the key features of Lean and Six Sigma and incorporate these features into an integrated approach towards improving business performance. Six-Sigma focuses on eliminating Critical to Quality (CTQ) issues affecting business organizations, while companies focus on systematically creating value and reducing waste (Thomas et al., 2016).

1.1. The principles of Lean

When done correctly, lean can create huge impact of business in efficiency, cycle time, lower costs and improved competitiveness. Eliminate waste –the non-value-added components in any process is the goal of lean–. And remember, lean isn't restricted to manufacturing. Inventory management, and even client interaction, Lean can improve how a team works together.

According to researchers (Sibalija & Vidosav, 2014) that the basic principles of making lean are: (a) Value flow, where the value flow for each product must be identified, implying both value added and non-value added activities. Value flow is the sequence of events that flow from concept to delivery, adding value to customer expectations. Lean overall purpose is to eliminate activities that do not create value. There are seven known wastes in manufacturing, one of which is waste which can be categorized into non-added value. On average, less than 1% of activity is value added, and typically, resources are focused on increasing 1% and ignoring 99% of opportunities, (b) Value, where the value for a particular product must be determined precisely from the point of view of the customer who uses it (c) Pull: The customer will actually draw value from the producer. In the production chain, when the customer last pulls the product, each production process triggers to produce the product simultaneously, (d) Flow: Flow value is determined by customer requirements and created without having to be interrupted. Flow can be understood as a continuous movement of product, which supports the flow of one part and work cell over a production line. In determining the steps for value creation it is necessary to pay attention to the strict order so that the product flows smoothly towards the customer. (e) Perfection: Perfection of production must be continuously attempt step by step. Since the determined value of the value flow activity is identified, wasted steps are eliminated, and flow and pull are introduced, the continuous improvement process is continued until the state of perfection is that no waste is made into a perfect value.

Muda is the Japanese term label for value creation through the elimination of wasteful activity, and is a basic Lean principle called "Toyota's seven wastes" as identified by Ohno (1988) in describing the Toyota Production System (TPS) in the general category: over-processing; overproduction; transport; unnecessary / excessive movements; waiting; defects; unnecessary inventory.

1.2. The concept of Lean

Make it earlier with no longer time and valuable with no waste generation is The Lean works on operation format. Simply performing better productivity in eliminating waste from the manufacturing process is The concept of lean manufacturing. maximize value to the customer while using a few resources as possible is The aims of Lean. So any activity that does not add value from a customer's point of view is waste (Sabale & Thorat, 2019).

1.3. The eight wastes of lean production

Listed below are eight wastes, or processes and resources, that add no value to customers: (1) Overproduction of the product, (2) Waiting, perhaps people waiting or equipment that is not needed, (3) Investing more time into a product than what the customer needs, such as a design that requires high-tech machinery or a lot of costs for features unnecessary, (4) Excess inventory, (5) Unnecessary transportation, (6) Unnecessary movement of people, equipment or machines, (7) unused waste of talent and ingenuity, (8) Disabilities, which require more a lot of work and costs for corrections.

1.4. The relationship between Six-sigma and lean principles

According to researchers Tohidi (2012), Process Improvement Efforts seek to correct problems by eliminating the causes of variations in the process while leaving the basic processes intact. Process improvement refers to the strategy of finding solutions to eliminate the root causes of performance problems in existing processes in our company. In Six Sigma terms, the Process Improvement team finds the critical X (cause) that creates the unwanted Y (defect) generated by the process. 5S is a set of techniques. They are used to improve workplace practices that facilitate visual control and lean implementation. 5S is the basis for continuous improvement, zero defects, cost reduction, and a

safe work area and is a systematic way to improve workplaces, processes and products through the involvement of production line employees. DMAIC (Define, Measure, Analyze, Improve, and Control) is a structured problem solving methodology that is widely used in business. These phases lead the team logically from defining the problem through implementation solutions related to the underlying causes, and establishing best practices to ensure solutions stay in place.

The relationship between the Six Sigma Model and Lean Principles is shown in Figure 1.

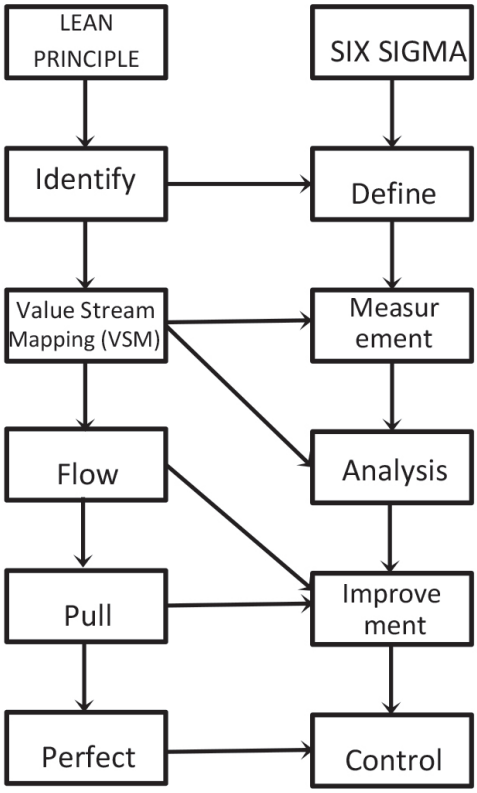

Figure 1. Relationship between Six Sigma Models and Lean Principles.

1. The first step in Lean starts from identifying problems that are directly obtained and understood from managerial descent to the production line, while in Six-sigma the Define step can be sourced from the production line, customer complaints or top managerial wish plans. 2. The second step is to carry out Value Stream Mapping, which is to identify the time required for each work process with a focus on added value to customers, this is the same as measuring the dependent variable (Y) at the Measurement stage and measuring the independent variable (X) at the analysis stage. 3. Flow and Pull steps, is an improvement step that must be done. Flow value is determined by customer requirements. In the production chain, when the customer last pulls the product, each production process triggers to produce the product simultaneously. 4. Perfect Step, is a step of stability of the improved process that we monitor at all times during the control phase.

Benefits of Lean-Six-Sigma (LSS) The following are the benefits of Lean-Six-Sigma (LSS): (Olanrewaju et al., 2019). 1. The process speed and output are uniform, so cycle times can be reduced. 2. Efforts to continuously increase productivity. 3. Reduction of defective products that are in the process of production. 4. Efforts to save space and reduce costs.

1.5. Obstacles and Difficulties implementing Lean Six-sigma

Based on the research of Albliwi et al, (2013) Lack of top management commitment and involvement, lack of communication, lack of training and education, limited resources and others are some common factors for failure in term of LSS implementation. Pereira et al., (2017) Only 10% or less of the companies trying to implement Lean Manufacturing practices are successful in understanding and implementing the philosophy in their processes. Lean production systems are quite difficult to implement. There are many difficulties for it on the side of the operational and supporting framework and, even today, they cause a number of problems, confusion and controversy. Even in companies starting a lean implementation process, the difficulty is just as great. Implementation of Lean Manufacturing is not an easy task, and there have been several issues and issues reported about the difficulties the company faced during implementation. The understanding and willingness of top management to make a very large investment so that this method can work is also an important obstacle. Extensive knowledge of lean and six-sigma based on the implementation of statistical science is a must for the success of lean six-sigma.

In addition to implementing LSS in the service industry, it is very difficult to do this because the basic reference of Lean and Six-sigma is the manufacturing industry.

2. Methods of Research

By reviewing the previously published literature this magazine addresses the most commonly resolved topics with the Lean Six-sigma (LSS) method approach in many sector. This research was initiated by obtaining scientific journals through academic journals in the field of LSS which were published in leading journal database. The research articles that are the researcher's concentration are related to LSS and are carried out in many sector. The articles are reviewed starting from articles published since 2009 ~ 2020, according to predetermined criteria, then searches can be carried out. The journals we reviewed come from many countries such as India, Portuguese, Italy, Sweden, Brazilia, Serbia, USA, UK, Malaysia, Jordan, Norwegian, Indonesia, South Afrika, Mexico, Poland, Egypt, Philipines, Purdue, Australia, Ireland, Thailand, Croatia, Irag, Lebanon, Russia, Slovak & Bangladesh. By using keywords, paper submissions can be determined.

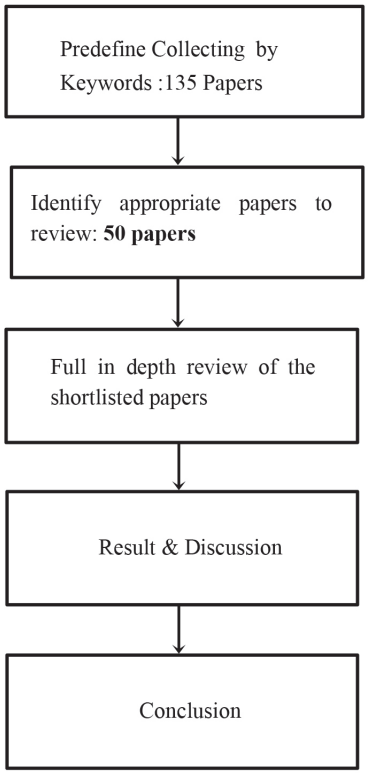

Figure 2. Study of framework.

3. Result & Discussion

Let us explain the findings from several journals that we have reviewed in terms of the object of research. A systematic literature review is conducted to identify relevant opportunities for the introduction and development of a successful Lean Six Sigma approach in many kinds of Industries. There are 50 papers that have been completed in-depth review. Consideration of the object of research and the results of each paper are evaluated. Table 1 shows the complete list of reviewed papers. There are several papers that have successfully implemented LSS in several organizational sectors.

Manufacturing: Ghaziabad, from India (2012) applied LSS in manufacturing company by a). Capabilities for Wider Widths Hard Alloys Rolling was Developed in Hot Rolling Mill and b) In the Hot Mill Process to eliminate the downtime due to strip / coil slippage during the 5xxx hard alloy winding, measurements of all parameters in Six Sigma are carried out. From this activity it can be concluded that, the practice of LSS helps the company to remain in the market with a relatively small investment for a new and more powerful hot mill. In Portuguese, Pereira et al., (2019) there are many areas of organizations in the Mold Industry, which can be said to have had great success when they made use of optimization tools. The event that contributed the most to the end can be done with Pareto analysis. Increased study of the Mold Industry is obtained from the study of CNC machines with the approach of applying Lean Six Sigma tools. In Sweden, Schön et al., (2010) did a research in three company. The surveys that are distributed to these companies are the result of research conducted. In many aspects of job satisfaction experienced by workers after following the LSS towards positive changes, these conclusions can be concluded through the survey results found. In Malaysia, Jirasukprasert et al., (2014) conducted an investigation into a rubber company to find the factors causing defects. After optimizing two production process variables, which in turn can help the organization learn to reduce defects, a reduction of about 50 percent in glove leakage defects can be achieved. an approach through Six Sigma and a streamlined problem solving methodology that can effectively improve the glove-making process by reducing the number of defects is the conclusion that can be given. Indrawati & Ridwansyah, (2015) from Indonesia, measure Six-sigma level in An Iron Ores Industry. Iron ore drying production is not optimal due to its low production efficiency, general and influential waste products are an indication that the processing is improper and produces defects. In this research, to increase the capability of the manufacturing

process, it is carried out using the lean Six-sigma method, the proposed improvement program is develop to overcome the problems through lean six sigma consistency. LSS has succeeded in improving organizational performance and its competitive advantage, the conclusions of several researchers who have conducted a comprehensive review and evaluation of the implementation of LSS in the organization. Researchers Taylor et al., (2011) from the USA made observations about dominant lean versus dominant Six Sigma in an article published in the International Journal of Lean Six Sigma. Finally, they recommend that Lean is dominant and consists of two subordinate methods - Six Sigma. and statistical process control can make significant progress to the organization.

Healthcare: Barnabé et al. (2016) did the observation in Healthcare institutions in Italy. Various results can be expected. First, increased efficiency as a result of the anticipated improvements in professional performance. The key LSS factors are employee empowerment, communication, institutional leadership, and personnel training, as the conclusion of the project. Arcidiacono & Pieroni, (2018) another researcher in the same object of observation in term of Healthcare in Italy. By improving the quality of experience felt by patients while reducing healthcare costs, this is the conclusion of the application of lean six sigma 4.0.

Oil & Gas: Nascimento et al. (2019) did observation oil and gas company in Brazilia to explore the synergy between Six Sigma principles and lean production (LP). For problem solving through continuous and gradual improvement, until they conclude that LSS is developed taking into account the integration of Six Sigma and lean production (LP) will provide a systemic and holistic approach.

Multi Object: Mvsit et al. (2016) from India, did measurement to evaluate enabler ratings is the basic framework of AHP. Albliwi, et al, (2013) find out there are 34 critical failure factors for the spread of LSS.

Garment: Rodrigues Nogueira et al. (2017) from India, did measurement defect in Textile industry by using Combining the variability reduction tools and techniques of Six Sigma is a function of Lean Sigma. Winning customer loyalty and improving bottom-line results, DMAIC is a proposed framework integrating Lean tools in the Six Sigma methodology. Following lean six sigma to find out the main defect causes, as well as the causal variables, and then suggest a logical solution to minimize the defects is the conclusion of this project. Another researcher Nedra et al. (2019) also from India,. to improve process performance for clothing in small-to-medium enterprises and SMEs. Perform a combination technique between applying PDCA, and controlling, improving each DMAIC step that is carried out continuously. The use of the PDCA-DMAIC technique is better when applied with a certified company, than with an uncertified one, it is much more effective.

Automobile: In USA, Ellis (2016). In the process of making a car, an exploration of the application of Lean Six Sigma is carried out to find the root causes of the inefficiency of the production process. The adoption of Lean Six Sigma to increase orders at car manufacturing facilities has successful in increased efficiency for the company.

Pharmaceutical: Al-shourah et al. (2018) calculated quality impact programs in Pharmaceutical Companies in Jordan by Simple Regression, according to the result of calculation they decided, in order to improve production performance there is an influence of the manufacturing system which we are familiar with the alpha (α) value which is statistically significant at the significance level ($\alpha \leq 0.05$).

Aerospace: In UK, Thomas et al. (2016) conducted research at Aerospace companies to create an integrated approach between Six Sigma and Lean elements. After calculating all the factors, they concluded a successful financial savings of more than £ 2 Million was proposed.

Telecommunications: In south Africa (Shuttleworth, 2015) conducted research in South African telecommunication companies, regarding when implementing LSS management support is very important. In the final section this research concludes that LSS ultimately contributes to improving yields and can improve service delivery.

Shipping: Another researcher from UK (Garza-Reyes et al., 2016) observing the framework of the ship loading process in the Iron Pellet Industry and commercial time as a form of LSS implementation to improve key performance and operating main indicators. After calculating all parameters and extract problem by using Value Stream Mapping (VSM), Result of this project can be save about $ 300,000 USD every year.

Education: Li et al. (2019) from Purdue, Doing observations in college, how to use Six Sigma can improve service processes. They realize that the strength of LSS in the service process in Higher Education has a very big impact, so that implementation must continue to be pursued.

Hospital: In USA, Furterer (2012) conducted research on applying Lean Six Sigma problem-solving methodologies and tools to improve linen loss in acute care hospitals. Improve the key operational metrics the Team is able to perform. He concluded that LSS was a great application of problem solving methodology and tools.

IT: Kundu & Murali Manohar (2012) conduct observations in the IT support services sector and identify CSFs from a lean implementation perspective. They concluded that the IT support services sector had not been systematically examined and investigated for the application of lean principles to the CSF section.

Financial: In Sidney (Chelliah & Skinner, 2016) conduct research to maximize financial benefits with the implementation of Lean Six Sigma. Finally, they recommend strategies for using key metrics to drive leadership-driven decisions about improvement.

Public Sector: Last, research the public sector, researcher from Malaysia, Kowang et al. (2019) did a research success factors for LSS implementation in private and public sectors. In this section, knowledge of LSS and a culture of continuous improvement that contributes to the sustainability of LSS implementation can be realized.

Table 1. Existing literature review of the Lean Six Sigma.

No	Paper Identity	Research object	Country	Result
1	(Ghaziabad, 2012)	Develop Ability to Eliminate break time and Hard Alloys with Wider Width Rolling in the Hot Rolling Mill process	India	Resulting in better order compliance and massive reductions in inventory, and cycle times were dramatically reduced from 47 to 20 days,
2	(Pereira et al., 2019)	The optimization of internal process	Portuguese	The lead time is 12 weeks, which corresponds to approximately 164 h of Cycle time (OCT), 23 h related to Change-over (C/O), totaling in average of 60% availability time.
3	(Barnabé et al., 2016)	Evaluation of Health institutions for performance improvement being analyzed	Italy	Significant savings of over € 28,000 annually which are then reallocated in a different and more efficient manner than over 65 days of hospitalization.
4	(Schön et al., 2010)	Six Sigma influences job satisfaction.	Sweden	Job satisfaction according to four categories of personal change; an overall assessment of the influence of Six Sigma on the company; influence on the organization of the careerist impression.
5	(Nascimento et al., 2019)	Six-sigma Principles and Exploring synergies of Lean Production (LP)	Brazilia	Consider the integration of PDCA (Kaizen), DMAIC methodology (from Six sigma) and LP principles, a conceptual framework of LSS can be proposed.
6	(Sibalija & Vidosav, 2014)	The approaches for integration of Six Sigma and Lean	Serbia	In general, to keep sustaining of the business by implementing LSS synergy.
7	(Furterer, 2012)	improve the linen processes	USA	By undertaking the implementation of automated linen and scrub dispensers and operational improvements, the Team was able to improve key linen operating metrics, saving $ 77,480 for the first year and a soil-to-clean linen ratio of 16%.
8	(Mvsit et al., 2016)	Ranking of these enablers and identification of appropriate enablers.	India	Lean six-sigma is structured as a hierarchy and pairwise comparison matrix is formed and arranged, to evaluate enabler ratings is the basic framework of AHP.

(Table 1, continued on next page)

No	Paper Identity	Research object	Country	Result
9	(Albliwi, et al, 2013)	Understand more deeply the critical failure factors for the application of LSS in various sectors	UK	In the organization there are 34 critical failure factors for the spread of LSS. Poor selection and priority of LSS projects, Lack of training Lack of top management attitudes.
10	(Kowang et al., 2019)	Success factors for LSS implementation	Malaysia	Important factors in the implementation of LSS, Top Management Support and Communication agreed by previous researchers as success factors for the Innovative Culture of LSS.
11	(Fullerton et al., 2014)	Operations personnel with their internal decision making can be supported by lean MAP	USA	Of the 244, there are 119 factories that have some form of calculating lean implementation.
12	(Taylor et al., 2011)	Lean dominant versus Six Sigma dominant	USA	There is an assumption that Lean Six Sigma is not standardized. The dominant Lean Six Sigma article ensures that Lean is the dominant philosophy and Six Sigma is the subordinate tool.
13	(Al-shourah et al., 2018)	In pharmaceutical companies to Improve production performance	Jordan	"There is a statistically significant impact of lean management and Six Sigma, quality programs, just in time, manufacturing Systems, at the level of significance ($\alpha \leq 0.05$) in Improving the Performance of Production in Pharmaceutical Companies in the Amman Stock Exchange".
14	(Assarlind & Aaboen, 2014)	Adopting Lean Six Sigma to identify strengths (in the form of converters and inhibitors)	Norwegian	The need for recognition in the adoption process at Peak Tech. The order of the Organization level from level 0 to level 1, and from level 1 to level 2. How they contribute to the enterprise adoption process and not such converters and blockers is more interesting.
15	(Jirasukprasert et al., 2014)	Reducing defective products process of rubber gloves in the manufacturing industry	Malaysia	From million product, found production defect (DPMO) from 195,095 ppm to 83,750 ppm, thus the practice of Six-sigma can increase the Sigma level from 2.4 to 2.9.
16	(Motiani & Kulkarni, 2019)	Business Process of Outsourcing and Knowledge Process in industry.	India	Organizational factors such as cost drivers and strategic alignment were observed variations. To ensure smooth implementation Top management commitment is a must in all cases.
17	(Siregar et al., 2019)	The focus on several journals published on a particular topic is subject to review	Indonesia	Almost all types of manufacturing industries such as shipping, automotive, paper, pharmaceuticals, iron, etc. 21 journals reviewed, there are 19 journals for case study of the application of LSS.
18	(Pervez et al., 2020)	A conceptual framework for the implementation of six sigma practices and lean - green	Malaysia	The framework which incorporates the practices of lean green six sigma's effect on the sustainability performance of SMEs.
19	(Hill et al., 2018)	Maintenance Repair and Overhaul (MRO) in an aerospace facility.	UK	Down from an average calls of 29 per month to just 13 per month for late calls.
20	Shuttleworth, 2015)	A South African telecommunications company Implementing LSS	South African	Top management support determines the success of the LSS project directly or indirectly.
21	(Valles et al., 2009)	Reduce the level of defects at a semiconductor company	México	Before the improvement, it was found that the Sigm level was 3.35 sigma and an increase of 0.37 sigma was obtained which represented the elimination of 1.88% units which did not match or equal to 18,788 PPM.

(Table 1, continued on next page)

(Table 1, continued from previous page)

No	Paper Identity	Research object	Country	Result
22	(Indrawati & Ridwansyah, 2015)	Improve the manufacturing process capability, In Iron Ores Industry.	Indonesia	The drying iron ore production process is not optimal because the production efficiency is only at the level of 52%. Process capability is at the 2.96 sigma level, because the Non Necessary - Non Value Added (NNVA) activity is 14.20% and Non Value Added (NVA) is 33.67%.
23	(Maleszka & Linke, 2016)	The impact of Lean Six Sigma tools in some polish production companies	Poland	The list of tools most often used by companies are: Pareto Diagram and Ishikawa Diagram 5S and Kaizen, Kaizen, 5S.
24	(Gijo et al., 2011)	Reducing defects in automotive companies in the fine grinding process.	India	In the fine grinding process defect can be reduce from 16.6 to 1.19%.
25	(Arcidiacono & Pieroni, 2018)	Increase the QOE felt by patients while reducing Health Care costs.	Italy	We can assume that most of the corrective activities should be carried out in this process with respect to the MHT value = 348 minutes.
26	(Garza-Reyes et al., 2016)	framework of the ship loading process in the Iron Pellet Industry and commercial time as a form of LSS implementation to improve key performance and operating main indicators	UK	The loading of ships can be increased processing capability and commercial time by more than 30 percent. Result of this project can be save about $ 300,000 USD every year.
27	(Ellis, 2016)	To improve the order processing process in an automobile manufacturing facility, determine the root causes of process inefficiencies and make recommendations	USA	Related to the order processing process can be done by postponing the order or updating the Spec Pro sooner will eliminate the most influential defects.
28	(Elbermawy et al., 2014)	Improving a Pharmaceutical Industry in Supply Chain processes.	Egypt	Order Preparation time from 206 to 121 Time/ mins.
29	(Sanidad & Dalimot, 2019)	Effects of implementing projects using Lean Six Sigma, in various companies in the Philippines	Philippines	"Determining Financial Needs" and "Dividend Policy" areas with 97% and 94%, respectively.
30	(Li et al., 2019)	Improving the service process in University with the application of Six Sigma	Purdue	The strength of Six Sigma in the service process in University can be seen through its application.
31	(Ahmed et al., 2018)	Lean Six Sigma effects in Hospital	Malaysia	In Malaysian health care organizations it was found that there was no significant relationship between top management commitment and quality performance.
32	(Rodrigues Nogueira et al., 2017)	The final product in the textile industry, defects that occur can be reduced	India	After applying lean six sigma the percentage of defects can be reduced from 8.25 to 2.63. and for the industry sigma level value, it shifts from Level 2.9 to Level 3.1
33	(Kundu & Murali Manohar, 2012)	CSFs is IT support services sector as a guideline	India	Certain important regulating and facilitating factors are the keys to a successful lean application.
34	(Chelliah & Skinner, 2016)	Maximize financial gain	Australia	Based on management practices that involve process management and strategic metrics, it is the project improvement strategy that should be chosen.

(Table 1, continued on next page)

(Table 1, continued from previous page)

No	Paper Identity	Research object	Country	Result
35	(Nedra et al., 2019)	for SMEs, small and medium enterprises in the clothing business, process improvements are carried out	India	The lead time decreased from 39.47 days to 30.23 days. Increasing the sigma level from the 1.45 level to the 3.85 level and increasing the Cp processability from 0.5 to 1.3 and
36	(Brown et al., 2019)	Surgery admission improvement rate (DOSA)	Ireland	The preoperative test duplication has decreased from 83 to <2% Surgery admission improvement rate has increased from 10 to 75%.
37	(Trakulsunti et al., 2020)	Dispensing errors in the inpatient teaching hospital pharmacy can be reduced	Thailand	Of the 20,000 days of hospitalization per month error expenditure has decreased from 6 to 2 incidents, representing a 66.66% decrease.
38	(Dewi et al., 2012)	Minimize waste in prime line International LTD	Indonesia	Waste in the production process is waiting with an incidence percentage of 95.81% and a sigma level of 0.00, a defect with a percentage of incidence of 2.64% and a level sigma 2.84, and also overproduction by percentage incidence of 0.76% and the sigma level of 3.55.
39	(Bratić, 2011)	At the Croatian graphics company, the Six Sigma Approach is carried out and presents the results of empirical research	Croatian	In a Croatian graphic company, Tools Analysis, Variance (48.15%), Regression Analysis (49.38%) and Process Mapping (56.79%) were carried out as part of the Six-sigma technique analysis.
40	(Ketan & Nassir, 2016)	Improvement of Aluminum hot extrusion process capability	Irag	profit increased from ID 127,000 to ID 223,000 per 1000 kg, sigma level was increased from level 1.4 to level 2.4, processing yield (Y) was increased from 46% to 81%, and DPMO reduction from 536,804 ppm to 185,795.09 ppm.
41	(Thomas et al., 2016)	Six Sigma Framework in an Aerospace Company and Strategic Lean	UK	Reducing Value-Added time by 5% and, reducing Non-value-added time by 44.5%, Building on 20.5% reduction in time, and increasing on-time-in-full (OTIF) delivery to customers by 26.5%.
42	(Sabry, 2014)	Implementation in some of Lebanese hospitals Performance indicators	Lebanon	Factors 1, 2, 3, 4, and 6 namely (executive commitment), (adopting a philosophy), (benchmarking), (training) and (closer supplier relationship) are the five critical success factors for the differences of the 17 quality factors of the Six- sigma program quality with Significant at the 5% level.
43	(Barnabé et al., 2016)	Conduct analysis and evaluation for performance improvement in health institutions	Italy	Significant savings of over € 28,000 annually which are then reallocated in a different and more efficient manner than over 65 days of hospitalization.
44	(Kremcheeva & Kremcheev, 2019)	Six Sigma method implementation in the educational process	Russia	The learning process before students gain competence, it requires input and output of skills and knowledge processes that are transformed and also expanded.
45	(Ha et al., 2016)	Quality improvement a mass Immunizations project at the U.S. Naval Academy	USA	The project implementation process proved to be controlled with a capability index of 1.18 and a performance index of 1.10, resulting in a damage rate of 0.04% and an average immunization waiting time decreased by 79% and staff decreased by 10%.
46	(Sachin & Dileeplal, 2017)	Improve the production process in a Foundry Industry	India	casting rejection decreased from a rate of 15.61% to 7.40%.

(Table 1, continued on next page)

(Table 1, continued from previous page)

No	Paper Identity	Research object	Country	Result
47	(Girmanová et al., 2017)	To avoid increased internal costs associated with poor product quality of metallurgical products	Slovak	The defective product indicator value per one million opportunities decreased drastically from 81,038 ppm or equal to 2.9 Sigma, to 39,636 ppm DPMO or equal to 3.3 Sigma.
48	(Prabu et al., 2013)	Quality improvement in foundry Process.	India	Increase Sigma level quality from 3.90 to 3.97.
49	(Al-Qatawneh et al., 2019)	to apply Six Sigma in the field of health care logistics so it is necessary to propose a framework	Jordan	This work expresses the idea of prioritizing all stored items based on performance, cost and criticality in hospital management.
50	(Rahman et al., 2017)	Reduce defect rate at Garment industry	Bangladesh	we can achieve the desired 2% breakdown rate by the end of the project deadline.

4. Mapping of the Journal

According to the papers mapping on figure 2~5, there are 50 papers reviewed in total, all of papers are published in the last 11 years (2009 – 2020). The papers are spreading into 12 different industries sector from manufacturing, Healthcare, Oil & Gas, Multi Object , Garment, Automobile, Public sector, Pharmaceutical, Aerospace, Telecommunications, Shipping, Education, Hospital, IT, and Graphic. Where the author as well as the object research location was spreading into 27 countries globally.

Most of the researcher from those 50 papers were observed the linkage between the implementation of LSS with Identify appropriate papers to review and the significant improvement of the organization as well as it increased customer satisfaction. Of course the author also includes several literature reviews as input on the obstacles and success of LSS implementation.

The following map journals are divided into 3 categories, namely the number of publications per year, the country of origin of the researcher and the third is the industry or material of the studied object.

The year of publication of the journal studied is as follows (Figure 3). From the graphs presented, most journals in 2016 & 2019 were 20%, followed by journals in 2014 was 12% and 2012, 2017 and 2018 as much as 8 %, the rest can be seen in the graphs.

The country of origin of the researcher can be seen in the Pareto chart (Figure 4), where the majority of the researchers are coming from India, as the research in manufacture, garment and IT.

The object of the study can be seen from Figure 5, where most of the research object comes from Manufacture. This survey literature uses random sampling, with the keyword “Lean Six Sigma” on data base provider in the international journal.

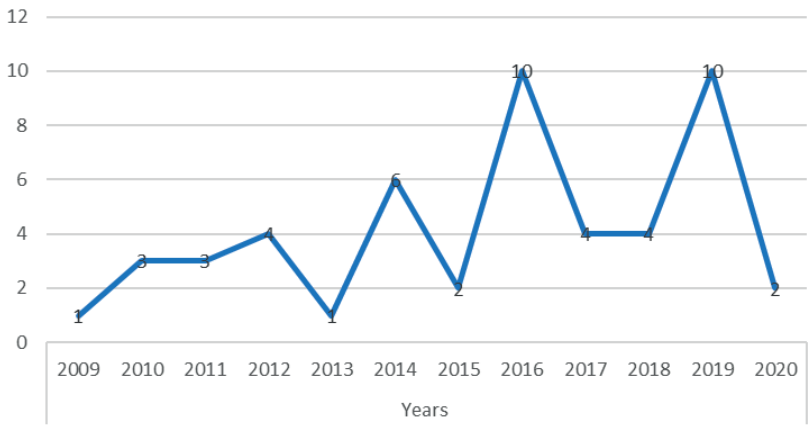

Figure 3. Years Publication.

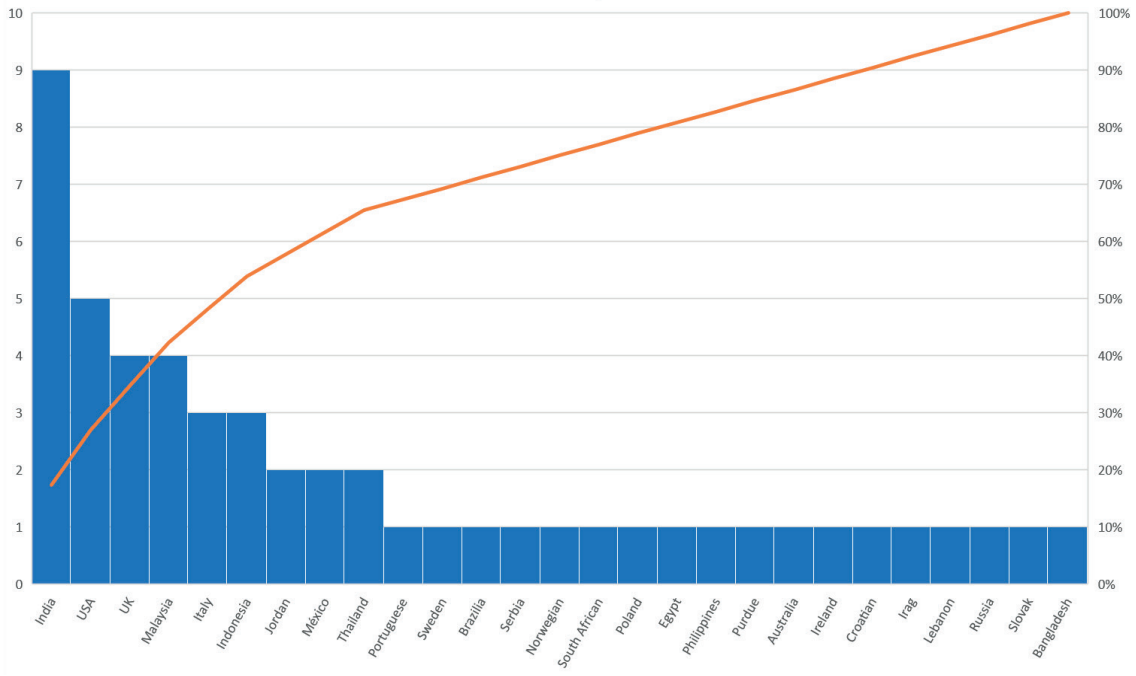

Figure 4. Country of Researcher.

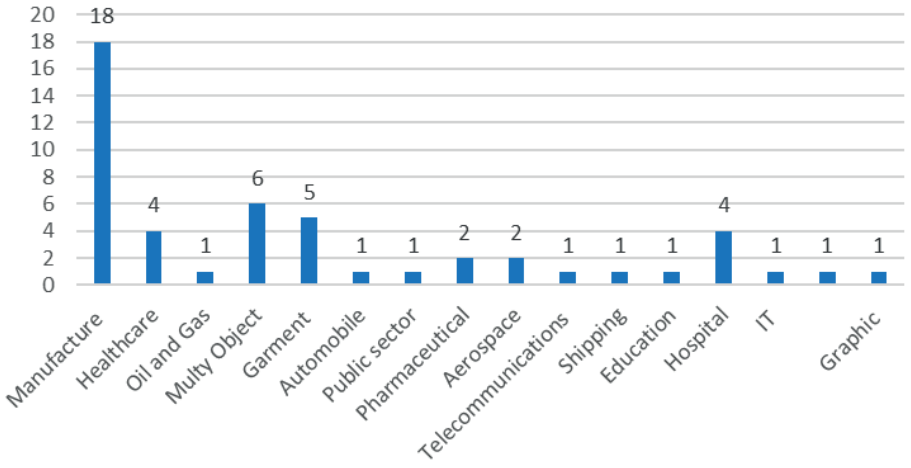

Figure 5. Research Object.

5. Lean Six Sigma and agenda for future research

Many countries in the world have implemented LSS extensively in many industrial sectors. In the current era, LSS is also still popular, which can be seen in the publication of research papers in the last 10 years which confirms that researchers are still interested in observing the implementation of LSS in organizations. With today's business environment and rapid change it is emphasized that LSS is still in use and still is appropriate.

For the future research framework on LSS, In preparation for the implementation of industry 4.0, it must be continuously improved and adjusted. This will enhance process improvement capabilities and product design capabilities that will benefit the

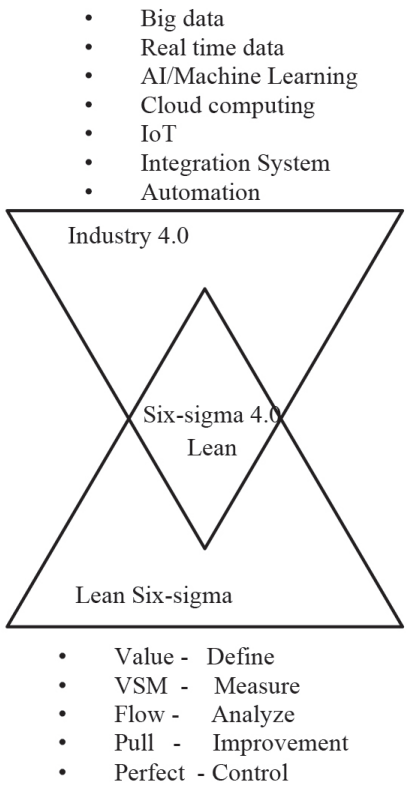

Figure 6. Future Research framework.

company. For future research, six Sigma collects data to attain its goal. Collected data should be analyzed to create an optimum and proper decision. However, Industry 4.0 technologies change together an enormous amount of information. Therefore, traditional data analysis techniques do not seem to be sufficient because they require more prolonged and value. It is possible to profit from advanced techniques, which are suitable for large data, like big data analytics and process mining, additionally to traditional techniques to create effective decisions, shown in Figure 6. Also, in the future research Collaboration of 2 components, there are industry 4.0 and Lean Six Sigma, can provide a guide that makes easier, faster, more reliable, and satisfied decisions with data for improving quality in processes.

With the use of industry 4.0 technology in the implementation of Lean Six-sigma, data input, data processing and analysis to conclusions can be made very quickly and accurately, which in turn can increase efficiency and increase productivity very significantly.

6. Conclusion

According to the mapping results. In accordance with the results of the mapping that has been made, the most published years can be published, in 2016 and 2019. In the research country section, India is the country that produces the most publications. The most research object comes from the manufacturing sector. It is realized that the results of the mapping above do not describe the real situation as a whole, but only a picture when collecting data according to keywords.

The main review of this article is a combination of Six Sigma tools and techniques and lean manufacturing principles that change the process level and product quality produced in the industry. The combination of the two concepts we call Lean Six sigma (LSS) is a powerful tool that can influence processes and customer / stake holder satisfaction in an organization. the adoption of Lean Six Sigma is still starting in the last decade or two in developing countries. In context, extensive records have reduced researchers' the increasing number of current research on lean-six-sigma is a testament to the great attention and research interest in this area. In developed countries Lean-Six-sigma has been practiced most of the time, but still focuses on interests in manufacturing processes and management activities. all types of industries can apply Lean-Six-sigma for better customer / stakeholder satisfaction and productivity through continuous improvement in business activities. (Olanrewaju et al., 2019).

For example base on Garza-Reyes et al., (2016) research concluded improvement both the capability of its ship loading process and commercial time by more than 30 percent, resulting in operational savings in the range of $300,000 USD per year. In the manufacturing section, the increase in the impact of improvements is felt to provide great benefits to the organization, this can be seen in Table 1, point to numbers 1, 2, 4, 8, 11, 12, 14, 15, 16, 21, 22, 23, 24, 38, 40, 46 and 47.

Then from the other side, we can see that LSS publications from year to year continue to increase, this shows that these tools have increased use in various sectors. In many countries in the world Lean Six sigma (LSS) is still widely used and applied in many industrial sectors. LSS focuses on providing the best product or service solutions and increasing customer satisfaction are the reasons why LSS is still suitable for the current situation, it is necessary to

improve service quality, organizational quality and product quality, as a whole.

Of course, there are obstacles in implementing LSS, such as lack of top management commitment and involvement, lack of communication, lack of training and education, limited resources and others implementation.

References

Ahmed, S., Abd Manaf, N.H., & Islam, R. (2018). Effect of Lean Six Sigma on quality performance in Malaysian hospitals. *International Journal of Health Care Quality Assurance*, *31*(8), 973–987. https://doi.org/10.1108/IJHCQA-07-2017-0138

Albliwi, S., Antony, J., Abdul Halim Lim, S. and van der Wiele, T. (2014). Critical failure factors of Lean Six Sigma: a systematic literature review, *International Journal of Quality & Reliability Management, 31*(9), 1012-1030. https://doi.org/10.1108/IJQRM-09-2013-0147

Al-Qatawneh, L., Abdallah, A.A.A., & Zalloum, S.S.Z. (2019). Six Sigma Application in Healthcare Logistics: A Framework and A Case Study. *Journal of Healthcare Engineering*, *2019*. https://doi.org/10.1155/2019/9691568

Al-shourah, A.A., Al-tarawneh, R.T., & Ali, F. (2018). *The Integration of Lean Management and Six Sigma Strategies to Improve the Performance of Production in Industrial Pharmaceutical*. *13*(8), 207–216. https://doi.org/10.5539/ijbm.v13n8p207

Arcidiacono, G., & Pieroni, A. (2018). The revolution Lean Six Sigma 4.0. *International Journal on Advanced Science, Engineering and Information Technology*, *8*(1), 141–149. https://doi.org/10.18517/ijaseit.8.1.4593

Assarlind, M., & Aaboen, L. (2014). *Chalmers Publication Library*.

Barnabé, F., Giorgino, M.C., Guercini, J., & Bianciardi, C. (2016). Performance Enhancement and Continuous Improvement in Healthcare: How Lean Six Sigma "Hits the Target." *International Journal of Business and Social Science*, *7*(5), 15.

Bratić, D. (2011). Six Sigma: A Key Driver for Process Improvement. *Communications of the IBIMA*, *2011*, 1–15. https://doi.org/10.5171/2011.823656

Brown, R., Grehan, P., Brennan, M., Carter, D., Brady, A., Moore, E., Teeling, S.P., Ward, M., & Eaton, D. (2019). Using Lean Six Sigma to improve rates of day of surgery admission in a national thoracic surgery department. *International Journal for Quality in Health Care: Journal of the International Society for Quality in Health Care*, *31*(1), 14–21. https://doi.org/10.1093/intqhc/mzz083

Chelliah, J., & Skinner, A. (2016). *Organizational Transformation: Strategic Application of Lean Six Sigma for High Performance*. *12*(1), 85–92.

Elbermawy, M.F., Al Manhawy, A.A., & Ibrahim, H.E.A. (2014). Implementation of Lean six sigma For Improving Supply Chain processes in a Pharmaceutical Industry. *International Journal of Scientific & Engineering Research*, *5*(8), 519–529.

Ellis, S.F. (2016). The application of lean six sigma to improve a business process: A study of the order processing process at an automobile manufacturing facility. *University of South Carolina Scholar Commons*, 139.

Fullerton, R.R., Kennedy, F.A., & Widener, S.K. (2014). Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices. *Journal of Operations Management*, *32*(7–8), 414–428. https://doi.org/10.1016/j.jom.2014.09.002

Furterer, S. (2012). Applying lean Six Sigma to reduce linen loss in an acute care hospital. *International Journal of Engineering, Science and Technology*, *3*(7), 39–55. https://doi.org/10.4314/ijest.v3i7.4s

Garza-Reyes, J.A., Al-Balushi, M., Antony, J., & Kumar, V. (2016). A Lean Six Sigma framework for the reduction of ship loading commercial time in the iron ore pelletising industry. *Production Planning and Control*, *27*(13), 1092–1111. https://doi.org/10.1080/09537287.2016.1185188

Ghaziabad, M.T. (2012). *Improvement process for rolling mill through the DMAIC Six Sigma approach*. *6*(3), 221–231.

Gijo, E.V., Scaria, J., & Antony, J. (2011). Application of six sigma methodology to reduce defects of a grinding process. *Quality and Reliability Engineering International*, *27*(8), 1221–1234. https://doi.org/10.1002/qre.1212

Girmanová, L., Šolc, M., Kliment, J., Divoková, A., & Mikloš, V. (2017). Application of Six Sigma Using DMAIC Methodology in the Process of Product Quality Control in Metallurgical Operation. *Acta Technologica Agriculturae*, *20*(4), 104–109. https://doi.org/10.1515/ata-2017-0020

Ha, C., McCoy, D.A., Taylor, C.B., Kirk, K.D., Fry, R.S., & Modi, J.R. (2016). Using lean six sigma methodology to improve a mass immunizations process at the United States naval academy. *Military Medicine*, *181*(6), 582–588. https://doi.org/10.7205/MILMED-D-15-00247

Hill, J., Thomas, A.J., Thomas, A.J., & The, S.E. (2018). The implementation of a Lean Six Sigma framework to enhance operational performance in an MRO facility The implementation of a Lean Six Sigma framework to. *Production & Manufacturing Research*, *6*(01), 26–48. https://doi.org/10.1080/21693277.2017.1417179

Indrawati, S., & Ridwansyah, M. (2015). Manufacturing Continuous Improvement Using Lean Six Sigma: An Iron Ores Industry Case Application. *Procedia Manufacturing*, *4*(less), 528–534. https://doi.org/10.1016/j.promfg.2015.11.072

Jirasukprasert, P., Garza-Reyes, J. A., Kumar, V., & Lim, M. K. (2014). A Six Sigma and DMAIC application for the reduction of defects in a rubber gloves manufacturing process. *International Journal of Lean Six Sigma, 5*(1), 2-21. https://doi.org/10.1108/IJLSS-03-2013-0020

Ketan, H., & Nassir, M. (2016). Aluminium hot extrusion process capability improvement using Six Sigma. *Advances in Production Engineering and Management*, *11*(1), 59–69. https://doi.org/10.14743/apem2016.1.210

Kowang, T.O., Yew, L.K., Hee, O.C., Fei, G.C., & Long, C.S. (2019). Lean Six Sigma Implementation: Does Success Means Sustainability? *International Journal of Academic Research in Business and Social Sciences*, *9*(6), 907–914. https://doi.org/10.6007/ijarbss/v9-i6/6051

Kremcheeva, D.A., & Kremcheev, E.A. (2019). Implementation of the six sigma method in the educational process. *Journal of Physics: Conference Series*, *1384*(1), 012022. https://doi.org/10.1088/1742-6596/1384/1/012022

Kundu, G., & Murali Manohar, B. (2012). Critical success factors for implementing lean practices in IT support services. *International Journal for Quality Research*, *6*(4), 301–312.

Li, N., Laux, C.M., & Antony, J. (2019). How to use lean Six Sigma methodology to improve service process in higher education: A case study. *International Journal of Lean Six Sigma*, *10*(4), 883–908. https://doi.org/10.1108/IJLSS-11-2018-0133

Maleszka, A., & Linke, M. (2016). Improvement of management process by using Lean Six Sigma tools in some big organisation of food industry. *Polish Journal of Natural Sciences*, *31*(1), 101–112.

Motiani, N., & Kulkarni, A. (2019). *Sustainability and Impact of Lean Six Sigma Practices: Learnings From Some KPO / BPO Organizations*. *11*, 442–452. https://doi.org/10.35940/ijitee.K1076.09811S19

Mvsit, S.K., Haleem, A., & Millia, J. (2016). *Lean six sigma implementation: An analytic hierarchy process approach Lean Six Sigma Implementation: An Analytic Hierarchy Process Approach*. *December 2014*.

Nascimento, D.L. de M., Goncalvez Quelhas, O.L., Gusmão Caiado, R.G., Tortorella, G.L., Garza-Reyes, J.A., & Rocha-Lona, L. (2019). A lean six sigma framework for continuous and incremental improvement in the oil and gas sector. *International Journal of Lean Six Sigma*, *11*(3), 577–595. https://doi.org/10.1108/IJLSS-02-2019-0011

Nedra, A., Néjib, S., Yassine, C., & Morched, C. (2019). A new lean Six Sigma hybrid method based on the combination of PDCA and the DMAIC to improve process performance: Application to clothing SME. *Industria Textila*, *70*(05), 447–456. https://doi.org/10.35530/it.070.05.1595

Olanrewaju, F., Chima Uzorh, A., & Nnanna, I. (2019). Lean Six Sigma Methodology and Its Application in the Manufacturing Industry – A Review. *American Journal of Mechanical and Industrial Engineering*, *4*(3), 40. https://doi.org/10.11648/j.ajmie.20190403.11

Pereira, A.M.H., Silva, M.R., Domingues, M.A.G., & Sá, J.C. (2019). Lean six sigma approach to improve the production process in the mould industry: A case study. *Quality Innovation Prosperity*, *23*(3), 103–121. https://doi.org/10.12776/QIP.V23I3.1334

Pereira, C.M., Anholon, R., & Batocchio, A. (2017). Obstacles and difficulties implementing the lean philosophy in Brazilian enterprises. *Brazilian Journal of Operations & Production Management*, *14*(2), 218. https://doi.org/10.14488/bjopm.2017.v14.n2.a10

Pervez, M., Abu, N., & Owee, T. (2020). *The Development of a Sustainability Framework via Lean Green Six Sigma Practices in SMEs Based upon RBV Theory*. *12*(5), 135–156.

Prabu, K., Makesh, J., Naveen Raj, K., Devadasan, S.R., & Murugesh, R. (2013). Six sigma implementation through DMAIC: A case study. *International Journal of Process Management and Benchmarking*, *3*(3), 386–400. https://doi.org/10.1504/IJPMB.2013.058162

Rahman, A., Shaju, S.U.C., Sarkar, S.K., Hashem, M.Z., Hasan, S.M.K., Mandal, R., & Islam, U. (2017). A Case Study of Six Sigma Define-Measure-Analyze-Improve-Control (DMAIC) Methodology in Garment Sector. *Independent Journal of Management & Production*, *8*(4), 1309. https://doi.org/10.14807/ijmp.v8i4.650

Rodrigues Nogueira, R., Lemos Cotrim, S., & Camila Lapasini Leal, G. (2017). Lean six sigma implementation on a yarn textile industry. *Revista Gestão Da Produção Operações e Sistemas*, *12*(2), 67–94. https://doi.org/10.15675/gepros.v12i2.1634

Sabale, S., & Thorat, S. (2019). *Applications of Lean Six Sigma*. 1999–2004.

Sabry, A. (2014). Factors critical to the success of Six-Sigma quality program and their influence on performance indicators in some of Lebanese hospitals. *Arab Economic and Business Journal*, *9*(2), 93–114. https://doi.org/10.1016/j.aebj.2014.07.001

Sachin, & Dileeplal. (2017). Six Sigma Methodology for Improving Manufacturing Process in a Foundry Industry. *International Journal of Advanced Engineering Research and Science*, *4*(5), 237172.

Sanidad, B.G., & Dalimot, M.M. (2019). The Effects of Lean Six Sigma Projects in the Companies. *Operational and Financial Efficiencies*. *21*(6), 82–88.

Schön, K., Bergquist, B., & Klefsjö, B. (2010). The consequences of six sigma on job satisfaction: A study at three companies in Sweden. *International Journal of Lean Six Sigma*, *1*(2), 99–118. https://doi.org/10.1108/20401461011049494

Sibalija, T., & Vidosav, M. (2014). *Integrating Lean with / within Six Sigma, International Journal 'Total Quality Management & Excellence'*. *38*(4).

Siregar, K., Ariani, F., Ginting, E., & P, T.D.M. (2019). Lean six sigma for manufacturing industry: a review Lean six sigma for manufacturing industry: a review. In *IOP Conference Series: Materials Science and Engineering*, *505*(1), 012056. https://doi.org/10.1088/1757-899X/505/1/012056

Shuttleworth, C.C. (2015). Management support for the application of Lean Six Sigma methodology to improve customer satisfaction in a South African telecommunications company. *Problems and perspectives in management*, *13*(4), 205-214.

Taylor, J., Sinn, J., Ulmer, J., & Badar, M. (2015). Proposed Progression of Lean Six Sigma. *The Journal of Technology Studies, 41*(1), 2-8.

Thomas, A.J., Francis, M., Fisher, R., & Byard, P. (2016). Implementing Lean Six Sigma to overcome the production challenges in an aerospace company. *Production Planning and Control*, *27*(7–8), 591–603. https://doi.org/10.1080/09537287.2016.1165300

Tohidi, H. (2012). Six Sigma methodology and its relationship with Lean manufacturing system. *Advances in Environmental Biology*, *6*(2), 895–906.

Trakulsunti, Y., Antony, J., Dempsey, M., & Brennan, A. (2020). Reducing medication errors using lean six sigma methodology in a Thai hospital: an action research study. *International Journal of Quality and Reliability Management, 38*(1), 339-362. https://doi.org/10.1108/IJQRM-10-2019-0334

Valles, A., Sanchez, J., Noriega, S., & Gómez Nuñez, B. (2009). Implementation of Six Sigma in a manufacturing process: A case study. *International Journal of Industrial Engineering: Theory Applications and Practice*, *16*(3), 171–181.

Dewi W.R., Setyanto, N.S., Tantrika, C.F.M. (2012). Implementasi Metode Lean Six Sigma Sebagai Upaya Minimasi Waste Pada PT. Prime Line Internasional. *Jurnal Rekayasa Dan Manajemen Sistem Industri*, *1*(1), 47–56.