A Systematic literature review of implementation six sigma in manufacturing industries

(Sebuah tinjauan literatur sistematis implementasi six sigma di industri manufaktur)

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Abstrak. Pendekatan Six Sigma mendapat banyak perhatian di berbagai sektor industri mulai dari industri manufaktur hingga industri jasa. Pengetahuan yang lebih spesifik tentang Six Sigma telah berkembang pesat. Sebagian besar pelatihan dan penelitian tentang Six Sigma dilakukan di berbagai Industri dan Universitas. Tinjauan pustaka terkait dengan Six Sigma bertujuan untuk memberikan gambaran tentang implementasi Six Sigma di industri manufaktur. Pendekatan Six Sigma yang telah diperkenalkan dan diimplementasikan sejak lama adalah DMAIC (Define, Measure, Analyze, Improvement, and Control). Makalah ini membahas literatur yang diterbitkan terkait Six Sigma mulai dari 2015 hingga 2020. Makalah ini melibatkan kajian studi dari 50 makalah yang terkait dengan implementasi Six Sigma pencarian database yang dikenal termasuk Elsevier, Science Direct, Emerald Insight dan Google Scholars. Tinjauan pustaka ini memuat hasil dari berbagai perspektif yang berbeda. Perspektif tersebut meliputi fokus industri, fokus jumlah distribusi menurut negara, fokus tahun publikasi dan fokus jumlah penerbit. Padahal, ini berguna bagi semua jenis industri manufaktur untuk mencari solusi masalah. Makalah tersebut juga memberikan keuntungan bagi peneliti selanjutnya untuk menambah literatur.

Kata kunci: six sigma, industri manufaktur, DMAIC.

Abstract. *The Six Sigma approach has received a lot of attention in various industrial sectors, from the manufacturing industry to the service industry. More specific knowledge about Six Sigma has grown rapidly. Much of the training and research on Six Sigma is carried out in various industries and universities. This literature review is related to Six Sigma's purpose to provide an overview of Six Sigma implementation in the manufacturing industries. The Six Sigma approach introduced and implemented for a long time is DMAIC (Define, Measure, Analyze, Improve, and Control). This paper discusses the published literature related to Six Sigma ranging from 2015 to 2020. This paper involves the study review of 50 papers related to the implementation of Six Sigma of known database search, including Elsevier, Science Direct, Emerald Insight, and Google Scholars. This literature review contains results from a variety of different perspectives. The perspective includes the focus of the industry, the focus of the number of distribution by country, the focus of the year of publication, and the number of publishers. This is useful for all types of manufacturing industries to find solutions to problems. The paper also provides advantages for researchers next to add to the literature.*

Keyword: six sigma, manufacturing industry, DMAIC.

1. Introduction

In the competition in the global market, a business strategy is needed to win the competition. The business strategy for achieving a competitive advantage is the successful implementation of a quality management system. Six Sigma is here as a tool to make it happen. When this, Six Sigma is one of the most popular initiatives in the sectors of industry, including industrial manufacturing. Six Sigma has developed rapidly in various industries.

The Six Sigma approach is used as a tool the problem solving of production that can be formulated breakthrough in the increase of production, reduce disability products, reduce the cost of production, reducing the time cycle of production, increase growth in the share of the market, to the retention of customers. The Six Sigma method is needed by companies, especially the production department, to improve the quality of their production. Especially in the era of technology such as now, the products' power competitiveness is very strict and demanding speed is high.

Generally, six sigma implementation is carried out in the manufacturing industry to reduce variability in processes to provide a better organization, product, or service to customers and reduce errors. (Ismyrlis & Moschidis, 2013). The companies that implement Six Sigma will benefit, including supporting sustainable success, strength value in consumers' eyes, accelerating improvements, setting new standards, and making strategic changes.

This literature review paper analyses strengths and weaknesses of six sigma implementation in manufacturing industries.

2. Literature Review

Six Sigma

According to (Vincent Gaspersz, 2002), Six Sigma is a vision of quality improvement towards the goal of 3.4 failures in a million opportunities (DPMO) for each product transaction (goods and services), an active effort towards perfection (zero-defect). Six Sigma is quality control and improvement method that has been implemented by the Motorola company in 1987. This method was developed by William B. Smith JR and Mikel J. Harry in 1981. The basic principle of Six Sigma is product improvement by making improvements to the process so that the process produces the perfect product. We have encountered many objectives of implementing Six Sigma in the industry. The Six Sigma methodology can improve quality, produce substantial cost savings, eliminate waste processes, and create effective work systems. Many researchers study the Six Sigma program and identify Six Sigma as an important tool for improving product quality and company profitability.

Strategy implementation of Six Sigma that was created by DR. Mikel Harry R. Schroeder is referred to as "The Six Sigma Breakthrough Strategy." This strategy is a systematic method that uses data collection and statistical analysis to determine the sources of variation and ways to eliminate them (Harry & Schroeder, 2000). Six Sigma method is applied to improve the production process or, more generally, achieve efficiency and optimize the production process. This is done so that the Six standard deviations (Sigma) between the mean and the closest breakdown limit do not exceed the specified limit.

The Six Sigma method also focuses on the process of preventing or minimizing product defects. The process of preventing product defects is carried out in several ways, which are also the goal of applying the Six Sigma approach.

DMAIC Strategy

According to (Vincent Gaspersz, 2002), two Six Sigma methodologies can be used: DMAIC and DMADV. DMAIC is used to improve the processes of business that exist, whereas DMADV is used to create the new design process and or Design of the product new in the way of such a form to produce a performance free of guilt (zero defect/error). This paper discusses the Six Sigma strategy with the DMAIC stages.

There are five stages, or steps basis in implementing the strategy of Six Sigma is that the Define-Measure-Analyze-Improve-Control (DMAIC), where the stage is a stage which is repetitive or forming cycle of improvement of quality with Six Sigma. The following is an explanation of each stage: (1) Define: A stage of beginning the focus to the identification of problems, the determination of the purpose of the process, and identifying the needs of customers are internally and externally through Pareto Chart & Critical To Quality. (2) Measure: Stages measure it objectively establish the foundation of improvement is a step of collecting the data with the purpose to establish a standard of performance through Pareto Chart, measurement of process capability (Level Sigma or process Sigma), as well as the Four Block Diagram. (3) Analysis: Phase Analysis isolate the cause of a major that is focused on by the team. In the implementation of the analysis is used is a hydraulic diagram fishbone and test hypotheses (Hypothesis test of a vital factor). (4) Improve: Stage improvement focuses on understanding fully the cause of a major who is identified in phase analysis, in phases improve, among others, namely Design of experiments, measurement of process capability after improvement (Level Sigma-Sigma process). (5) Control: Stage set standardization, control, and maintenance the process has been improved and enhanced in term length to prevent potential problems that will occur or when there is a change of processes, personnel work, and change of management of Statistical Process Control (SPC). DMAIC is used when a company already has a product finished or products that are still in the stage of the process but have not reached the specifications needed by the customer.

3. Method

This paper's purpose is to explore more deeply the implementation of Six Sigma in the manufacturing industry. Studies carried out by men notice database famed, including Elsevier, Science Direct, Emerald, and Google Scholars. This paper's purpose of elaborating on knowledge about the value of Six Sigma in the industry, consider Six Sigma as an organizational strategy, and search ways to get more insight into Six Sigma.

In the literature review, several steps must be executed so that the systematic and directed implementation. The first step is to formulate the problem. In this stage, the writer is required to choose a topic that matches the issue taken. Problems must be written completely and accurately. Then the second step is looking for literature and journals. At this stage, the writer looks for literature relevant to the research and then looks for an overview of the research topic. After that, review according to topic based on research sources. The third step is to evaluate or identify the literature. Search results are sorted as case studies or focus industry, focus number of distribution by country, focus year of publication, and the number of publishers. The data collected, analyzed, and the results are presented in graphical form. At this stage, look for the similarities and inequalities of the literature obtained. Then compare from various perspectives, then make a summary. The fourth step concludes the identification of all the literature obtained. The last stage is publishing in national and international journals. More details can be seen in Figure 1.

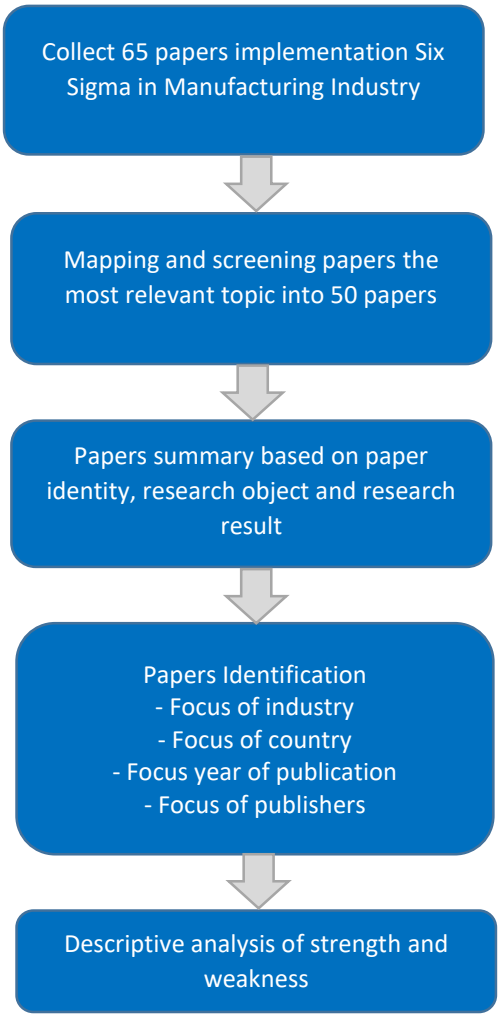

Figure 1 Study Framework

4. Result and Discussion

Papers Summary

This paper identifies 50 papers related to the implementation of Six Sigma in the manufacturing industry. The selected papers or articles will be analyzed. The analysis was carried out based on the researcher and year, research object, and research results. The author summarizes them in Table 1.

Table 1 Existing Literature review of Six Sigma in Manufacturing Industries

No	Paper identity	Research object	Result
1	(Jirasukprasert et al., 2015)	Defects reduction in a rubber gloves industry	Decrease the DPMO value from 195,095 to 97,569 and increase the Sigma value from 2,4 to 2.9
2	(Manohar & Balakrishna, 2015)	Reduce defect in the wheel production plant	The defect rate was reduced to 1.45% from 1.64% for Ingates and 0.69% from 0.77% for Cracks.

No	Paper identity	Research object	Result
3	(Suresh et al., 2015)	Defects reduction in manufacturing automobile piston ring	Decreased the rejects from 38.1% to 23.1%
4	(Shokri et al., 2015)	Reducing the scrap rate in an electronic manufacturing	Scrap rate decreased to 99.03% First Run Yield (FRY) from 98.4% FRY, and Sigma level increased from 3.65 to 3.85
5	(Caesaron, 2015)	Quality improvement of a process handling painted Body BMW X3	There are four types of dominant defects in the handling process, namely flex 31.3%, chip 24.7%, contamination 18.7%, and scratch 13.3%
6	(Srinivasan et al., 2016)	Enhancement Sigma level of furnace nozzle	The DPMO value decreased from 35,000 to 15,000, and the Sigma level increased from 3.31 to 3.67
7	(Pugna et al., 2016)	Improve assembly process in the automotive company	Cpk increased from 0.96 to 1.72; the short-term Sigma Level increased from 2.9 to 5.2.
8	(Gupta et al., 2016)	Improvement process in amplifier manufacture	The Sigma level value increased from 3.35 to 3.58
9	(A. Yadav & Sukhwani, 2016)	Quality improvement of a Clutch plate company	The DPMO value decreased from 68,181 to 9,090, and the Sigma level increased from 2.99 to 3.86
10	(Hadidi et al., 2017)	Improving aesthetic defects in aluminum profiles facility	Increasing the quality by increasing the Sigma level from 3.01 to 4.00
11	(Khatak, 2017)	Reduce Rejection in Screw manufacture	The Sigma level value increased from 1.12 to 5.79
12	(Singh et al., 2017)	Reduction defect in the manufacturing industry	The Sigma level increased from 2.89 to 3.16, and the processing yield increased from 91.73% to 95.19%
13	(Prashar, 2017)	Reduce defect in a Shock absorber assembly components	Reduced defect products from 10% to 3% and financial savings of $ 5,000 per year
14	(Zaman & Zerin, 2017)	Reduce defect in sewing manufacturing	The percentage of damage decreased from 11.67 to 9,672, and the Sigma level has increased from 2.69 to 2.8
15	(Pinto et al., 2017)	Improve in an extrusion process	A decrease of 0.89% in the work-off indicator generated by the production system resulted in financial savings of over € 165,000 / year
16	(Ghaleb et al., 2017)	Reduce cycle time and defects in cement bag manufacturing	2.3% Sigma level with increased in the net profit of the company per year were achieved
17	(Sachin & Dileeplal, 2017)	Improving the manufacturing process in a foundry industry	Decrease the DPMO value from 222,000 to 84,000 and increased the Sigma value from 3.7 to 4.0
18	(Wulandari, 2017)	Quality improves in hijacker company	Decreasing the DPMO value from 12602.79 to 9774.89 and increasing the Sigma value from 3.70 to 3.84
19	(Imtihan et al., 2017)	Increase the quality of a body inner	Increasing the quality by increasing the Sigma level from 3.14 to 4.32
20	(Bharara, 2018)	Reduction of a defect in a vehicle assembly	Increase the Sigma level from 2.76 to 3.12.
21	(Senjuntichai, 2018)	Reduction defect in ready rice packaging	After repair, the percentage of total defects decreased by 56.42% from 5.14% to 2.24%

No	Paper identity	Research object	Result
22	(Sreedharan et al., 2018)	Defect reduction in electrical parts manufacture	Reducing defective products to 1,300 PPM
23	(Ahmed et al., 2018)	Defect reduction in a home appliance company	Defects in aluminum products decreased from 10.49% to 6.1%, and Six Sigma levels increased from 2.8 to 3.06.
24	(Belu et al., 2018)	Quality improves with external customer automotive	Reducing the DPMO value from 6000 PPM to 2000 PPM and increasing the Sigma value from 2.4 to 2.9
25	(R. Sharma et al., 2018)	Defect reduction in an automobile manufacturing	Decrease the DPMO value from 121,550 to 6,263 and increase the Sigma value from 2.67 to 4.11
26	(Damsiar et al., 2018)	Reduce reject painting process	Decrease the DPMO value from 151,361 to 15,431 and increase the Sigma value from 2,4 to 3,7
27	(Suprayogi, 2018)	Quality improvement of a tank washer	Reduce the number of rejects from 11% to 2%. The Sigma level increased from 2.73 to 3.326
28	(Supriadi & Deviyanti Sri, 2018)	Quality control of a good day Cappucino	Decreased the DPMO value from 5868 to 350, and the Sigma value increased from 4.02 to 4.89
29	(Rahayu & Darvin, 2018)	Quality improves in the ceramic tile industry	The number of defects is 4375 DPMO, with a Sigma level of 4.13.
30	(Rahman et al., 2018)	Quality improves in the garment industry	Reduction of defects by 35%. Sigma level increased from 1.7 to 3.4
31	(Nelfiyanti et al., 2018)	Quality improvement of a kiwi paste industry	The Sigma value increased from 4.20 to 4.75, with the DPMO value from 3497 to 568
32	(Raman & Basavaraj, 2019)	Reduction defect in a capacitor manufacturing	The results of the implementation show a significant increase in product quality and a reduction in costs.
33	(Chartmongkoljaroen et al., 2019)	Defect reduction in jewelry manufacture	The company was able to reduce the rate of resin breakdown and also improve the modeling process.
34	(M. Sharma et al., 2019)	Reduction of defects in the lapping process of silicon wafer manufacturing	Decreased the rejects from 4.43% to 0.02%
35	(N. Yadav et al., 2019)	Reduce defects in the glass manufacturing industry	Decreased the rejects from 2,295 pcs to 1,040 pcs/ month. It reduces the variable cost, consumables, and manpower cost per month.
36	(C.R. & Thakkar, 2019)	Reduce defect in a cabinet door manufacturing	Decreasing the DPMO value from 23,271 to 15,873 and increasing the Sigma value from 3.49 to 3.67
37	(Uluskan & Pinar Oda, 2019)	Quality improves household appliance manufacturing	The Sigma level value increased from 3.1 to 4.4
38	(Memon, 2019)	Defect reduction in an automobile company	The defect rate was reduced by 90% (from 132 to 13 defects) in the chassis track and 80% (from 157 to 28 defects) in the cutting line.
39	(Dewi & Ummah, 2019)	Quality improvement of a product roof	Decreased the DPMO value from 29311 to 8974.35, and the Sigma value increased from 3.35 to 3.99
40	(Manjunath et al., 2019)	Reducing the rejection rate of engine valve	The repair results can reduce the rejection rate in the grinding unit

No	Paper identity	Research object	Result
41	(P. Sharma et al., 2019)	Quality improves in Micro, Small, and Medium Enterprises (MSMEs)	The Sigma level value increased from 3.33 to 4.07
42	(Amrina & Firmansyah, 2019)	Decrease defect in O-Ring manufacture	The defect in O-Ring products decreased to 0.83%, and the Sigma value increased to 4.363%.
43	(Hernadewita et al., 2019)	Quality improves in magazine production	From the research results, the current production Sigma value is 3.6 or a decrease in DPMO value 15,919.
44	(Ahmad, 2019)	Quality improvement in chair production	The DPMO value is 47,361, and the Sigma value is 3.17
45	(Priya et al., 2020)	Product defect analysis in automotive assembly	Reduced 19 minutes of processing time and decreased defect ratio by 37.2%
46	(Costa et al., 2020)	Quality improvement of a pin insertion	Increased Sigma level from 4.22 to 4.92
47	(Ferrer-rullan et al., 2020)	Improving cash flow deficit in food manufacturing	The result balances cash flow and avoids having to ask for bank credit.
48	(Vanany et al., 2020)	Defect reduction in Halal food manufacturing	The DPMO value was also reduced from 3,211 to 2,414 ppm, and the Sigma level was improved from 4.23 to 4.35.
49	(Haryanto & Bachtiar, 2020)	Quality improvement of a Bar Comp Side Stand K81	The results showed that the DPMO value was 10330 and the Sigma value was 3.81
50	(Supriyati & Hasbullah, 2020)	Quality improvement of a painting process	The results of the improvement show the DPMO value of 7619 and the Sigma value of 3.9

Papers Identification

The identification of literature will be identified from various perspectives. The perspective includes the focus of the industry, the focus of the number of distribution by country, the focus of the year of publication, and the number of publishers. Six Sigma implementation is very popularly used in the manufacturing industry. More will be discussed here in the automotive industry. Figure 2 informed that Six Sigma is more widely implemented in industrial automotive. This is in line with the growing trend of the automotive industry. In automotive manufacturing companies, Six Sigma is used as a tool to improve the quality of production. Also, the Six Sigma strategy is the goal of reducing cycle times and increasing customer satisfaction in determining the optimal level and cost of service quality.

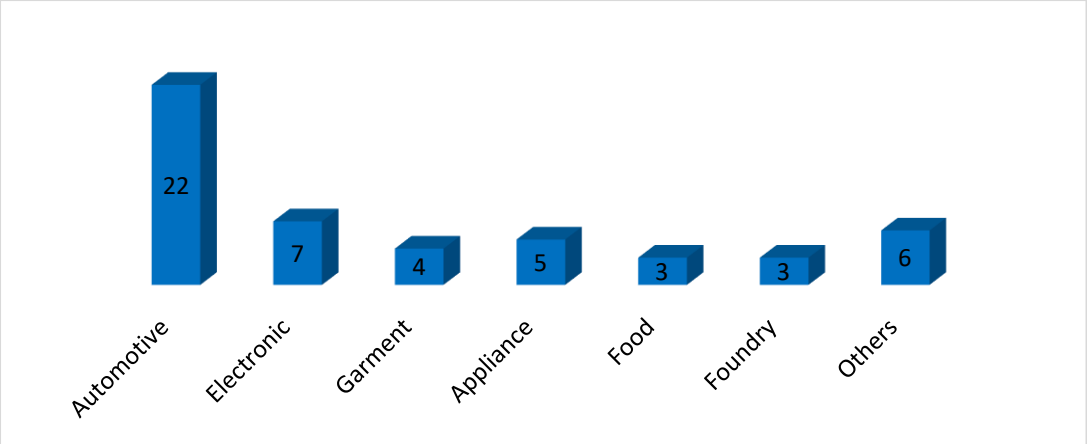

Figure 2 Focus of Industry.

Figure 3 analyzes the distribution of Six Sigma publications in manufacturing companies. India is the most frequently implemented Six Sigma. In this case, Six Sigma neglects, especially in developed and developing countries. Growth in India is in the figure of 7.9% per year, the projected growth in the economy's complexity. Reports have indicated that India has a lot of opportunities that have not been utilized in various industries and encourage growth and the creation of fieldwork. With the growth of the economy and the progress of India's scientific knowledge that sustained, the country is rated to be in the path of the right to be a state of the most powerful in the world. Then Six Sigma present in the implementation in manufacturing enterprises, in particular, to reduce the variability in the process, so that giving the organization, product or service that is good to customers, and reduce errors.

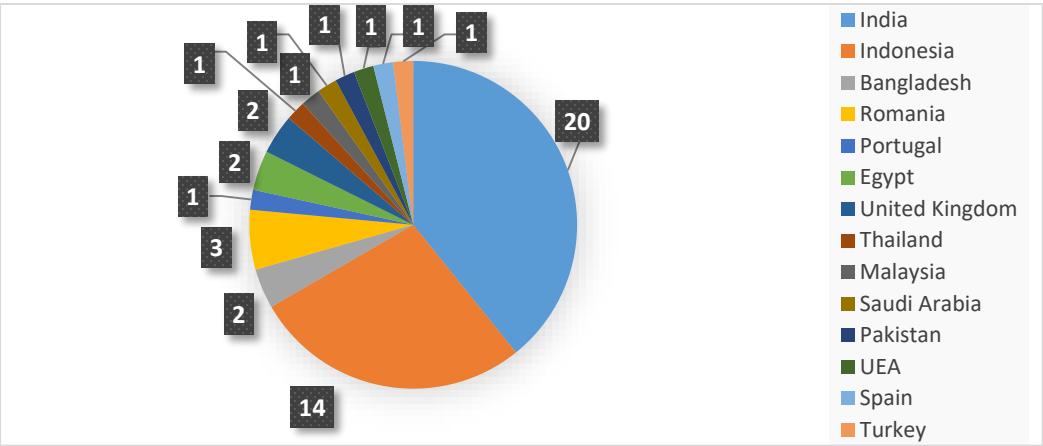

Figure 3 Focus of Country.

Figure 4 shows that Emerald Insight Publisher was most frequently searched during the 2015-2020 period (Figure 5). This is evident in identifying the paper, at most be the number of publisher emerald insight. The author suggests researchers use Emerald Insight as a reference in collecting reference sources in research because Emerald Insight is also a reputable journal publisher.

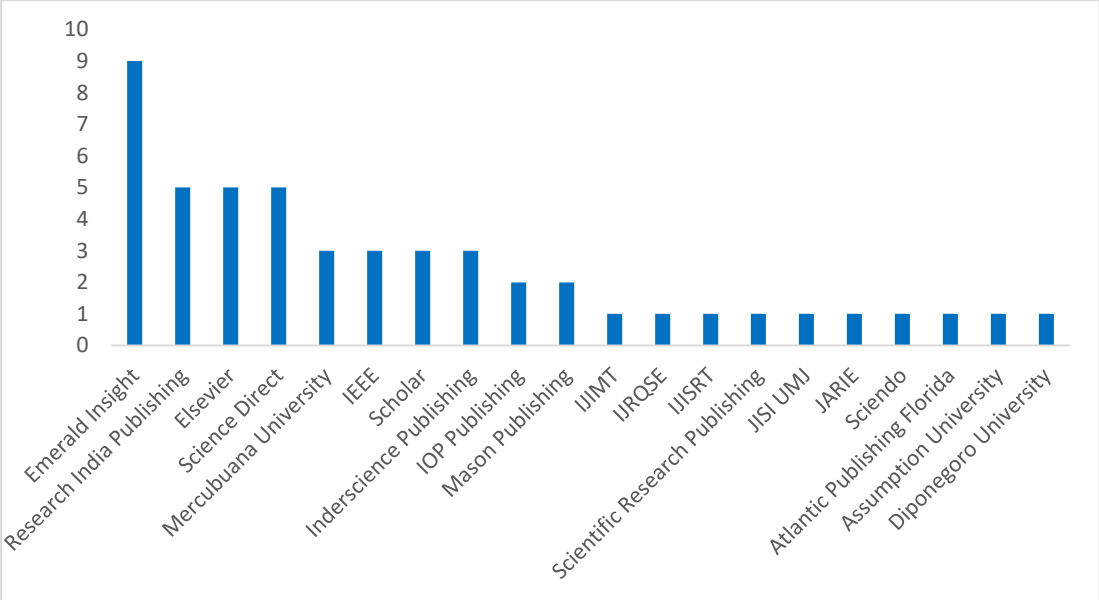

Figure 4 Focus of Publishers.

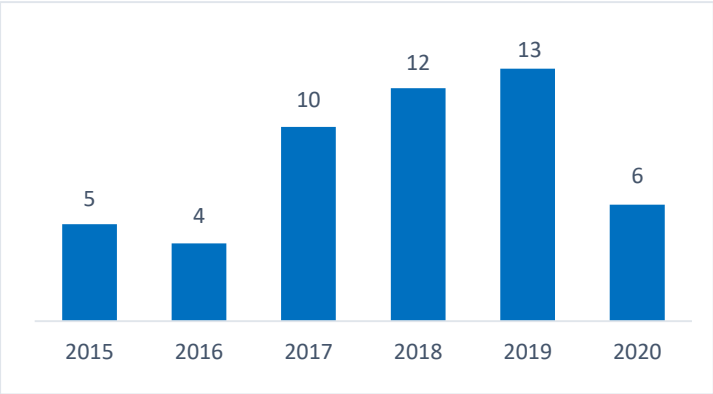

Figure 5 Focus Year of Publication.

Strength Analysis

In this literature study, the authors found the strength of all the journals that had been analyzed. Strength is based on three perspectives, namely journal writing, industry, and science

1. Journal explained in a clear and complete ranging from the abstract, introduction, review literature, methodology, results & discussion, and conclusions.
2. The advantage of the perpetrator of business to apply the method of Six Sigma is to get the slim, reduction of time of the cycle, and minimum cost.
3. We provide new references for the next researchers in problem-solving related to implementation with the Six Sigma approach.

Weakness Analysis

In addition to the literature study's strengths, the author also found several weaknesses based on perspectives, namely journal writing, industry, and science.

1. The format of writing journals are not organized, so that makes the writer difficulty in identifying literature.
2. The approach of Six Sigma requires a time that is very long in the implementation. Need stages which systematic to get a result that is best and necessary monitoring it regularly.
3. There are many new tools in modern life, so that researchers have many options in solving problems. As a result, the Six Sigma approach is neglected.

Benefits of implementing Six Sigma in the Manufacturing Industry

A review of 50 scientific articles related to the implementation of Six Sigma in the manufacturing industry has provided several benefits for companies. The application of Six Sigma in a company is a breakthrough strategy that allows the company to make extraordinary improvements. The following are some of the benefits of Six Sigma for manufacturing industrial companies, namely: increase profits and financial savings of the company, increase customer satisfaction, reducing the cost of the production process, reduce cycle times, improve product quality, and improve the process better.

Based on the many advantages obtained by implementing Six Sigma, it is recommended that future research use this approach to solve cases of problems that occur and to get benefits, especially in the manufacturing industry.

Gaps and Relations between Lean, Six Sigma and industry 4.0 for future research

Currently, it has entered the industrial era of 4.0. All production processes in the manufacturing industry have used a variety of sophisticated technologies. This is one reason for obtaining an effective and efficient process to win over the competition in the global market. In the current condition, the Six Sigma methodology is still done traditionally. For example, data collection and storage is still done traditionally. This, in data analysis, requires a long time. From now on, everything about data has changed. And this is where industry 4.0 can play its role. With the Internet of Things (IoT), the amount of data available will grow larger than it is today. It's no secret that the Internet of Things (IoT) is poised to have a big impact on the manufacturing industry. IoT helps companies Design, manufacture, and sell their products. IoT will be very important to reduce downtime due to unpredictable production facilities, especially in the manufacturing industry. However, before it can be used, the data must be formatted to be analyzed for business-enhancing insights. It is the first step in the combined implementation of Six Sigma with Industry 4.0 in the manufacturing industry. Analyze the data to find out where the operation is and what changes need to be made.

In future research, besides the combination of Six Sigma with industry 4.0, Lean can also be combined. Currently, the implementation of Six Sigma purpose only to reduce the height of product defects. So in the future, this method can be combined with lean. Lean is a concept created to increase process speed and product quality by simplifying the value stream. This purpose of identifying and eliminate activities and processes that are already consuming time and resources but do not have any added value for the company's goals.

So that Lean Six Sigma has the purpose of improving process performance by eliminating waste and achieving high levels of quality by investigating and eliminating the root causes of defects and minimizing process, product variability, and obtaining results or outputs that have added value for customers. By aligning Lean, Six Sigma, and industry 4.0, companies can better utilize large amounts of data to make operations more efficient and provide quality products to customers. The combination of Lean, Six Sigma, and industry 4.0 for future research can be seen in Figure 6.

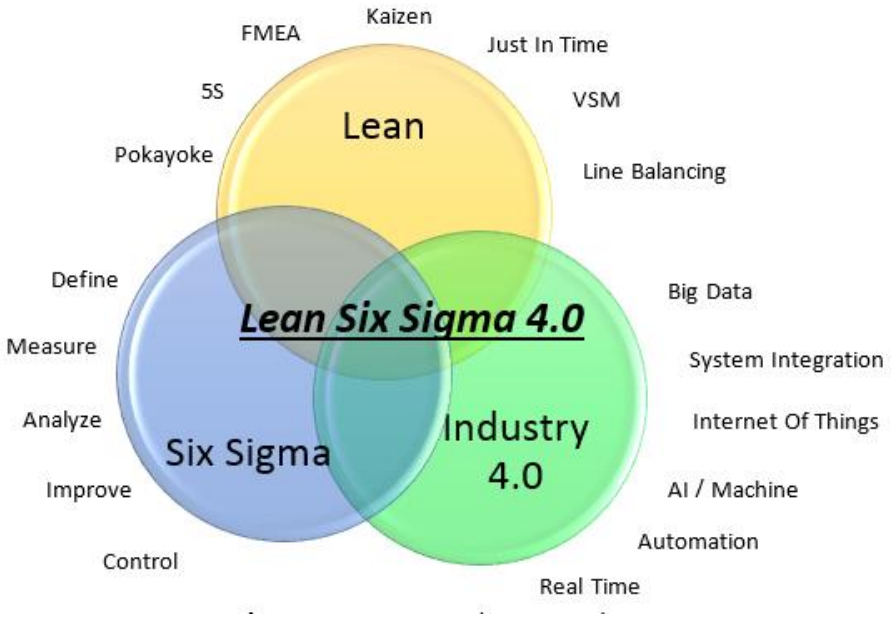

Figure 6 Future Research Framework.

5. Conclusion

Six Sigma approach is a structured and systematic methodology for improving a process focused on reducing process variance as much as possible, minimizing defects (products/services that fall outside of specifications) by using statistics and problem-solving tools intensively. Six Sigma's main focus as a management system is on three things, namely, the focus on customers, processes, and data management. This paper identifies that of the 50 journals analyzed, almost all of them can improve the quality of products produced or manufacturing companies' processes. This is a benchmark for manufacturing companies to provide an overview of tools for solving quality-related problems. Because with improvements with the Six Sigma approach, companies can get many benefits, including changes in product and service quality, increased productivity, lower costs, reduced defective products, and problems that can be resolved quickly. This paper suggests that the implementation of Six Sigma can be applied in the SME industrial sector because financial SMEs often experience obstacles.

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