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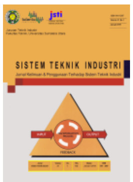

# A Systematic Literature Review of Six Sigma Implementation on the Automotive Component Industry

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**Abstract.** The main purpose of this white paper is to analyze current research on Six Sigma in the auto parts industry and identify opportunities for further research. This study used a systematic literature search of the most recent scientific articles (2013-2022) searched using specific inclusion and exclusion criteria. His two main categories of research goals emerged. The development of Six Sigma and the impact of Six Sigma. In recent years, research on the impact of Six Sigma is the most popular and has always been there from year to year, while research on the development of Six Sigma is the least popular. The study can provide insights to researchers, consultants and quality managers in developing and implementing Six Sigma in the automotive components industry sector. This research found that there is a lot of research on the complete Six Sigma methodology in the automotive component industry, especially research on the impact of implementing Six Sigma. From these findings, the main avenue for future research can be identified, namely Six Sigma Digitalization.

Keyword: Six Sigma, Automotive Component Industry, Systematic Literature Review (SLR), DMAIC

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## 1. Introduction

Increased international competition is one of the most important achievements of economic globalization. The speed and quality of achieving superior performance in a competitive world depend on the selection of appropriate methods and the use of organizational capacity and its key competencies. The automotive industry is one of the most active industries dealing with quality improvement, lower production costs and continuous improvement activities [1].

The development and implementation of an effective quality strategy are important factors for the long-term success of an organization [2]. In this sense, the Six Sigma methodology is a project-oriented approach to reducing process variations and errors, i.e., increasing process capability. Six Sigma was first developed by Motorola Inc. in 1986. Six Sigma is a powerful method for

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improving quality and reducing the error rate. Over the years, Six Sigma has evolved greatly in both manufacturing and service companies. Six Sigma is one of the best techniques for improving business processes. Six Sigma is a teamwork-based project to solve important customer and process problems [3].

The rest of this paper is presented as follows: Section 2 presents a literature review of Six Sigma; Section 3 presents the methodology to systematically review Six Sigma research in the automotive component industry; Section 4 presents the current state-of-the-art and future direction of Six Sigma research in the automotive component industry; and finally, Section 5 presents the conclusion of this study.

The results of the Six Sigma concept facilitate the achieving of almost 'zero defect manufacturing' and collecting high profits. The Six Sigma concept allows organizations to make fewer than 3.4 mistakes per million opportunities (DPMO). To achieve this goal, two approaches are followed. Projects that lead to defect prevention must be carried out in the organization by implementing the DMAIC (define, measure, analyze, improve and control) phases [4] and Six Sigma applications can better impact operational efficiency and consistency to improve business performance and align with customer needs [3].

## 2. Literature Review

In this increasingly advanced and growing global market competition, people's perspective in choosing a product has changed. It has not only grown in terms of costs, but also in terms of quality. Therefore, most companies assume that good quality is the most important thing since quality is the fulfilment of services to consumers [4]. One of the most important factors in improving product quality is quality control, which is part of the production process. To produce the highest quality products, companies must make quality improvements and process improvements in the hope of achieving the level of product defects until there are no defects [5]. Companies often use the Six Sigma method to control the product quality by minimizing the number of defects [6][7]. The Six Sigma methodology focuses on deficiencies and variations, beginning with the identification phase of the critical quality elements of a process through determining suggestions for improving the deficiencies or deficiencies that are encountered. Steps to reduce errors or failures are carried out systematically by defining, measuring, analyzing, improving and controlling. According to Paul in 1999, this systematic step is known as the 5 phases of DMAIC. DMAIC is carried out systematically based on science and facts to achieve the Six Sigma target of 3.4 DPMO (Defects per Million Opportunity) and of course increase the profitability of the company [4]. It states that Six Sigma is a tool or tool used to improve processes through customer focus, continuous improvement, and the involvement of people inside and outside the organization [7].

In this 4.0 industrial era, competition is becoming increasingly fierce, and quality products and services are a requirement for competitive advantage and the need to ensure the sustainability of business processes [4]. The DMAIC problem-solving methodology was one of several techniques used for product quality [8][6][7]. Six Sigma is a quality control and improvement method implemented by Motorola since 1986. Six Sigma is a form of quality improvement towards the target of 3.4 defects per million opportunities (DPMO) for each product, both goods and services reduce the number of defects. Six Sigma can also be defined as a business process improvement method that aims to find and reduce the factors that cause defects, reduce cycle times and production costs, increase productivity, meet customer needs, achieve optimal machine utility, and get better results [9]. Both in terms of production and service. This method is based on DMAIC, which stands for Define, Measure, Analysis, Improve and Control.

The Six Sigma concept facilitates achieving almost 'zero defect manufacturing' and collecting high profits. The Six Sigma concept allows organizations to make fewer than 3.4 mistakes per million opportunities (DPMO). To achieve this goal, two approaches are followed. Projects leading to error prevention should be carried out in the organization by implementing the Define, Measure, Analyze, Improve and Control (DMAIC) phases [4]. In this paper, we will show various implementations of Six Sigma and DMAIC to minimize the chance of product defects in the production process in the automotive component industry.

## 3. Methodology

This study presents the SLR approach to the current state-of-the-art of Six Sigma research on the automotive component industry. Fink [10] A research literature review is a systematic, explicit, and reproducible method of identifying, assessing, and synthesizing the existing collection of completed and recorded work produced by researchers, scholars, and practitioners. A search for the application of the Six Sigma approach was conducted on Google Scholar from a special range of issue years from 2013 to 2022 with the keyword Six Sigma in the Automotive Industry. According to Cruz-Benito [11], this methodology could be structured following the steps as shown in Figure 1.

### 3.1. Define Research Objectives

The methodology outlined above serves as a framework for this study, which aims to achieve the following objectives. Firstly, the study aims to examine the recent implementation of the six-sigma methodology within the automotive component industry. By analyzing real-world cases and examples, the researchers seek to gain insights into the application of six sigma principles, techniques, and tools in this specific sector. This examination will provide a comprehensive understanding of how six sigma is being utilized and the impact it has had on various aspects of the automotive component industry.

Secondly, based on the findings and observations from the study, the researchers intend to propose a current research gap. This involves identifying areas where further investigation or improvement is needed in relation to the implementation of six sigma in the automotive component industry. By identifying these research gaps, the study aims to contribute to the existing body of knowledge and provide valuable insights for practitioners, researchers, and industry professionals interested in optimizing quality and process efficiency in this field.

### 3.2. Define Inclusion Criteria

The systematic literature review (SLR) for this study will adhere to two specific inclusion criteria. Firstly, scientific articles included in the review must mention both "six sigma" and "automotive component industry" in either their titles or keywords. This criterion ensures a focused examination of the implementation of six sigma within the broader business process of the automotive component industry, rather than limited aspects or specific tools of six sigma. By applying this criterion, the study aims to gain insights into the overall application and impact of six sigma in this industry.

Secondly, the SLR will only consider scientific articles published within the last 10 years, covering the period from 2013 to 2022. This timeframe selection allows for the inclusion of recent research and developments in the field, ensuring the review captures the most up-to-date insights, methodologies, and case studies related to the implementation of six sigma in the automotive component industry. By focusing on literature from this specific period, the study aims to provide valuable and relevant information for the objectives at hand.

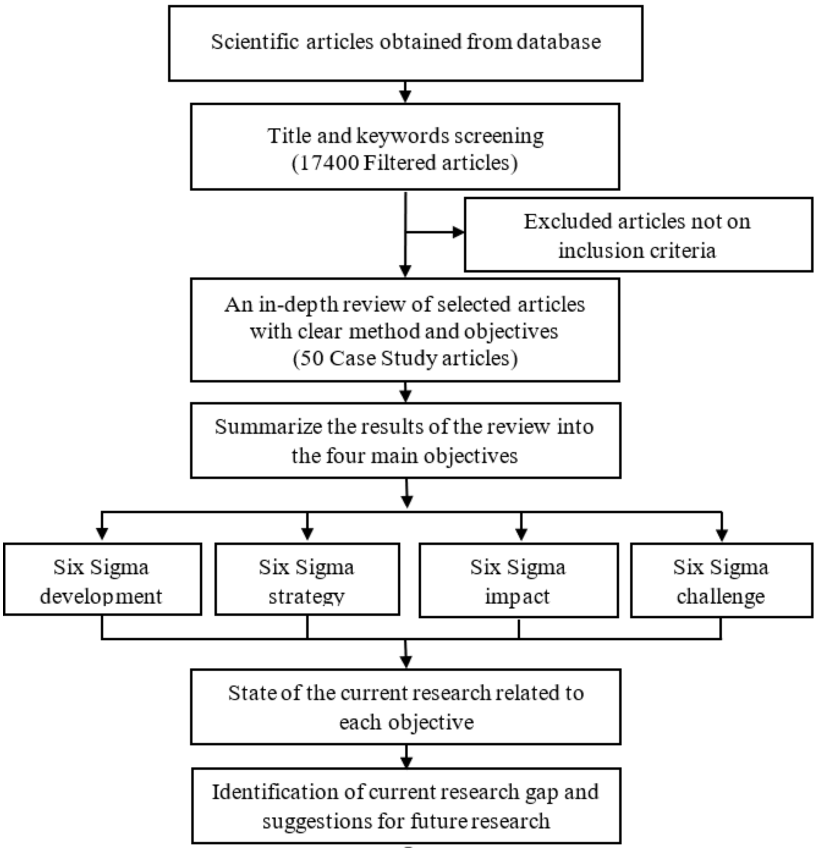


**Figure 1** Applied research framework based on SLR methodology

### 3.3. Search Scientific Database

The database used in this criterion is Google Scholar & Proquest Databases, which is widely used around the world, covering not only journals but also conference proceedings, books, and thesis or dissertation reports.

### 3.4. Assess and Screen the Results

Assessment and screening are necessary to select scientific articles with high relevance to the research objectives and inclusion criteria.

### 3.5. Analyze and Discuss the Results

Selected scientific articles will be analyzed and mapped into comparison tables to make the current state of research easier to observe and infer.

### 3.6. Propose Current Research Gap

From the current state of research mapping, the gap in current research will be observed and then proposed.

## 4. Results and Discussion

### 4.1. Scientific articles classification

This study identifies attributes contained in the scientific articles to offer insights into the development, implementation strategy, impact and challenges of six sigma on the automotive component industry. Scientific articles about six sigma implementations were collected from 2013 to 2022. A rigorous screening and review process as in Figure was done resulting in 50 relevant scientific articles on the automotive component industry and a case study that could be seen in Figure 3.

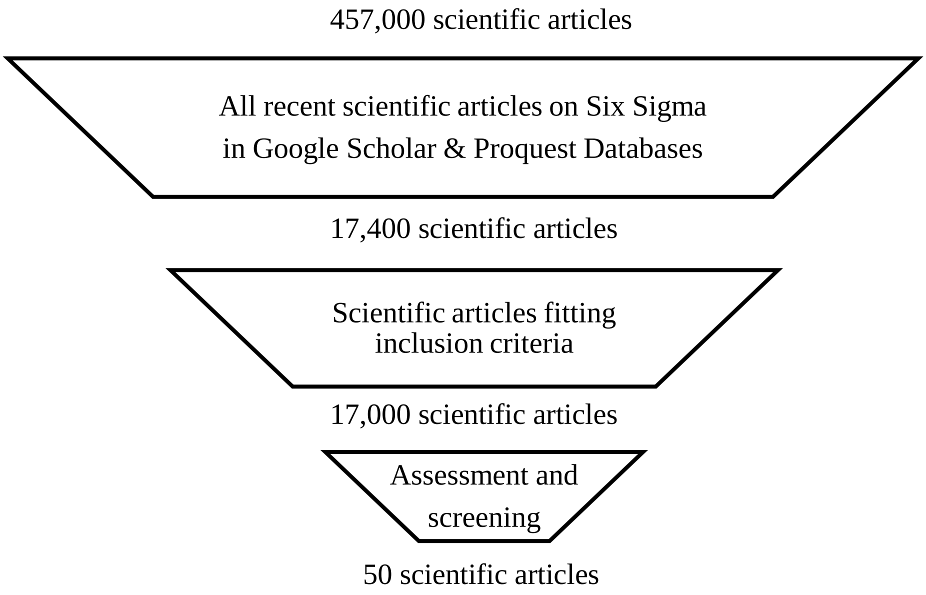


**Figure 2** Screening and review process of scientific articles based on SLR methodology

This study finds that the number of published articles in 2013 and recent years is relatively in decline, as seen in Figure 5. Regarding the publication region, it is found that the Asia region has significant contributions in recent years, that is Indonesia (37 articles), India (10 articles), Malaysia (2 articles), and Iran (1 article). Article classification by publication region is presented in Figure 6.

**Table 1** Systematic Literature Review on recent six sigma implementation in the Automotive component industry

| No. | Articles Identity | Research location | Research Object | Result |
|---|---|---|---|---|
| 1 | (Sundana & Yusuf 2013) [12] | Indonesia | Reducing defects on radiator assembly | Increased sigma value of 3.83 to 4.10 by submitting several proposed improvements in the production process |
| 2 | (Sharma et al. 2014) [13] | India | Increasing process capabilities on engine crankshaft process | Increased process capability (CP) from 1.29 to 2.02 and increased process yield (CPK) from 0.32 to 1.45 by reducing crankshaft end-boring process variation during engine manufacture |
| 3 | (Raju et al. 2014) [14] | India | Reduce defects in steering gear products | Raise the sigma level from 3.86 to 4.20 with improved backlash nuts on steering gear products |
| 4 | (Rijanto 2014) [15] | Indonesia | Quality control in the alloy wheel machining process | Increased process performance in March 2013 CP value of 1.00 and CPK 0.91 (with 3,798 DPMO, April 2013 CP value of 1.10 and CPK of 1.05 (with 2.73 DPMO), May 2013 value CP of 1.54 and CPK value of 1.54 (with 3.4 DPMO) |
| 5 | (Danny 2014) [16] | Indonesia | Quality improvement in automotive exhaust products | Sigma and DPMO values in 2013 amounted to 3.73σ and 12,879 DPMO showing automotive component companies can compete with other competitors' companies |
| 6 | (Yorie & Putro 2014) [17] | Indonesia | Reducing waste in the OEM parts production process | It is expected that the results of Sigma Waste Delays are 1.66σ, Waste Defect in the induction process of 2.29σ and Waste Motion of: 2.35 when applying Six Sigma 3σ. |
| 7 | (Irawan 2014) [18] | Indonesia | Quality improvement in the assembly of four-wheeled vehicles | The level of sigma level after the results of the new repair reached 5.02σ with the target 6σ |
| 8 | (Parwati 2014) [19] | Indonesia | Reducing the product defect's part front fender in the painting process | Sigma-level research results at PT. Abc is 3.25 with the main causes of NG spots |
| 9 | (Suseno 2014) [20] | Indonesia | Quality control of line Z production process of kijang cars | The results of the Sigma level calculation are at a level of 4.7 with a DPMO value of 732 with the source of the causes of the problem, there are machines, humans and the environment |
| 10 | (Misra & Chauhan 2015) [21] | Indonesia | Lower rejection on casting components in-house block machines | Reducing component rejection from 7.8% to 1.54% in the blurry hole in the bypass flap housing |

| No. | Articles Identity | Research location | Research Object | Result |
|---|---|---|---|---|
| 11 | (Abdul Rahman et al. 2015) [22] | Malaysia | Increased painting process on vehicle assembly | Reducing failure in the painting process of an average of 10 DPUs to less than 3 DPUs by reducing fibre defects |
| 12 | (Caesaron 2015) [23] | Indonesia | Reducing defects in the handling painted body BMW X3 process | The BMW X3 Painted Body driving process is still within the control limit, no defect is out of control |
| 13 | (Christoper & Suliantoro 2015) [24] | Indonesia | Quality control on Part NXS-001 | The result of part NXS-001 part is equal to 23,348.3 DPMO or 3.4σ |
| 14 | (Sudarwati & Wijaya 2015) [25] | Indonesia | Reducing defects in Metal Finish in the Welding Process | The decrease in the DPU of 0.005 to 0.002 in bump defects and flow-out defective reduction of 62.3% in the welding process |
| 15 | (Zahara 2016) [26] | Indonesia | Quality control part trim rear quarter right APV arena | The increased level of sigma product quality trim rear quarter right after the repair is 5563 DPMO with 4σ |
| 16 | (Kawi 2015) [27] | Indonesia | Quality control on disk brake products | After a repair of a decrease in product defects from 79% to 1.3% |
| 17 | (Yadav & Sukhwani 2016) [28] | India | Reduce rejection on the coupling part | Increased level of sigma process from 2.99σ to 3.86σ by reducing the defect of the clutch plates |
| 18 | (Norzaimi and Ani 2016) [29] | Malaysia | Reduce product defects in the car audio assembly process | Increased process capabilities of (CP) 0.96 to 2.14 and process performance (CPK) increased from 0.80 to 1.84 with process improvement in car audio assembly |
| 19 | (Sucipto et al 2016) [30] | Indonesia | Reducing cushion seat mount FU 150 products defects | Memorize the proposed improvement for the problem of defective products on the Cushion Seat Mount FU 150 |
| 20 | (Ritme et al. 2016) [31] | Indonesia | Control reject contamination on marking on the mark scan pack process | The increase in yields from 97.64% to 97.80% and the Sigma level rose from 4 <σ <5 to 5 <σ <6 |
| 21 | (Kusumo 2016) [32] | Indonesia | Minimization of waste in the accu making process | Reducing waste with a total production rise from 499,608 to 1,067,886 Accu Plate |
| 22 | (Kaushik & Kumar 2017) [33] | India | Reducing waste and improving the quality of seat slide lock nuts | The application of Six Sigma can raise the Sigma level from 1.59σ to 5.53σ by varying the size of the lock nut on the chair |
| 23 | (Noori & Latifi 2017) [34] | Iran | Reduce defects in the grinding process on the machine shaft | The application of Six Sigma and the improvement of organizational management can increase the Sigma level from 0.9σ to 3.0σ |
| 24 | (Imtihan 2017) [35] | Indonesia | Quality improvement in the inner body automotive component | Increased level of sigma from 3.14 σ to 4.32 σ on the inner body with redesigned production equipment |
| 25 | (Anggarini 2017) [36] | Indonesia | Defect reduction in the accu paste process | Decrease in defect/unit value from 4.197% to 0.948% in the battery paste process |
| 26 | (Swastika Eryan et al.2017) [37] | Indonesia | Quality improvement on button door lock control products knob | Product Manufacturing Button Door Lock Control Knob has a Sigma level of 3.72 and provides a proposed improvement in the manufacturing process |

| No. | Articles Identity | Research location | Research Object | Result |
|---|---|---|---|---|
| 27 | (Djalmono et al. 2017) [38] | Indonesia | Reducing product defects in the cylinder part master | Sigma's value in the 2dP type cylinder painting master process between 3.581 and 3,812 shows that the production of the 2DP type cylinder painting master is at the industrial average level in Indonesian |
| 28 | (Widyaningsih 2107) [39] | Indonesia | Minimizing waste in the process of mainframe production | The results of the most influential 3 waste analyses of the production process, namely Transportation, Waste Excess Processing and Waste Waiting |
| 29 | (Erizal 2017) [40] | Indonesia | Quality analysis product panel front door outer toyota kijang capsules | The total sigma value for the manufacture of the front door Kijang Capsule is 3.52. The most common type of disability is the type of Ding and Dents defects |
| 30 | (Ambar et al. 2018) [41] | Indonesia | Product quality control stay headrest | Increased Sigma level from 4.12σ to 4.29σ on Prduk Stay Headrest |
| 31 | (Christy 2018) [42] | Indonesia | Quality improvement in wheel products | The results of the level of sigma obtained were 3.39 to spoke the rim cracked, 3.82 pieces of rims, and 3.65 face shrinkage |
| 32 | (Gandhi et al. 2019) [43] | India | Reduce rejection on the cylinder block | Increased level of sigma process from 2.88σ to 3.28σ by lowering blowholes defects in the cylinder block |
| 33 | (Ranade 2019) [44] | India | Reduce defects in tire making | Increase the Sigma level from 1.25 to 1.80 by increasing the frequency of cleaning and painting systems in the tire production process |
| 34 | (Pathmanaban 2019) [45] | India | Increase the results of the graduation rate from the Assembly Machine ALH4CT | The increase in the output process from 95% to 99% on the ALH4CT engine assembly |
| 35 | (Nindiani et al. 2019) [46] | Indonesia | Decrease in the defect of the garnish-assembly tailgate product in the painting process | Increased sigma value of 2.90 to 3.10 on garnish-assembly products |
| 36 | (Fitrianto 2019) [47] | Indonesia | Design improvement of four-wheel vehicle products | The results of the DPMO calculation of 30.770.03 and the average level of Sigma level is 3.3696 |
| 37 | (Haryanto 2019) [48] | Indonesia | Decrease in defective paint dust spots fuel tank products in the painting process | Increased value of Sigma Level 3.88 to 4.94 by Standing the Parameter Setting Temperature and Speed Conveyor |
| 38 | (Trimarjoko et al. 2019) [49] | Indonesia | Reduce defects in tire product | Increasing the baseline performance process from Sigma level 4.48 to 5.02 Sigma can reduce costs from IDR 1,427,500.00 to IDR 161,000,000 or 88.69%. |
| 39 | (Maryani et al. 2020) [50] | Indonesia | Improvement process capabilities on casting aluminium alloy wheels | The increase in product performance from PC=0.81 becomes PC=1.4, and the rising level from sigma level=2.9 becomes sigma level=4.0 by eliminating product leakage problems |

| No. | Articles Identity | Research location | Research Object | Result |
|---|---|---|---|---|
| 40 | (Setiawan et al. 2020) [51] | Indonesia | Reducing roof panel product defects on the quality of the packaging process | The results of the improvement can reduce the DPMO value of 33,500 units to 2,050 units and increase the Sigma level from 3.33 to 4.37 |
| 41 | (Supriyati 2020) [52] | Indonesia | Analysis of automotive painting components | The highest percentage of defects in row 1 is 6.86% and the highest type of freckle/large defect is 36.3%, DPMO value of 7619 and a sigma value of 3.9 |
| 42 | (Armandhika Utomo et al. 2020) [53] | Indonesia | Reducing defects on parts bracket comp jack | Increased value of sigma from 3.3 to 4.0 with the repair of an outflow defect on the part bracket comp jack |
| 43 | (Sundarmali 2021) [54] | India | Reducing defects in the motor starter shaft assembly | Increased level of sigma process from 1.0σ to 2.0σ by reducing defects in the motorcycle starter shaft assembly process |
| 44 | (Bhargav et al. 2021) [55] | India | Reducing variations in the process of making bearings | Increase the level of sigma from 2.5 to 3.5 by reducing variations in the racing process and outside bearing ball bearings |
| 45 | (Guleria et al. 2021) [56] | India | Reduce rejection in gear making | Increase the Sigma level from 4.37 to 4.81 in variations in measurements above teeth (mot) and circle pitch Diameter (PCD) in gear making |
| 46 | (Ariyanto et al. 2021) [57] | Indonesia | Improving the quality of the work process on motorcycle tire products | Reducing the Nylon scrap on a motorcycle tire product tire from 5880 ppm to 3454 ppm with a maximum target of 4270 ppm |
| 47 | (Sukirno et al. 2021) [58] | Indonesia | Reducing Defect on Pipe Exhaust XE 611 | The enhancement of the Sigma level from 4.16σ to 4.58σ by lowering defect welding holes |
| 48 | (Rani et al. 2021) [59] | Indonesia | Quality improvement in plastic automotive parts painting | A decrease in the reject of 20.58% by achieving Sigma values to 4.39 with improvements to the causal factors namely material |
| 49 | (Suda 2021) [60] | Indonesia | Improve production quality on a compression cylinder | The results of the Sigma level increased from 3,5005 to 3,9033 on a compression cylinder |
| 50 | (Prasetyo 2022) [61] | Indonesia | Minimizes waste and increases work efficiency in the production of leaf spring automotive | The calculation of the DPMO value and Sigma level in the production process of leaf spring is equal to 14,947,7807 or 3.67σ |

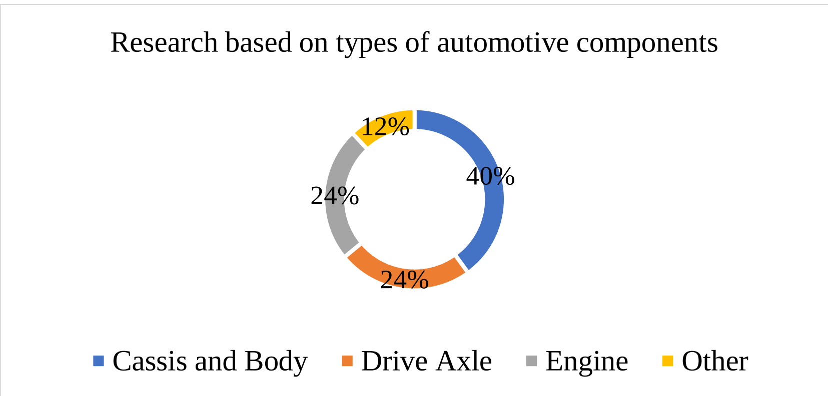


**Figure 3** Classification of scientific articles by type of automotive component

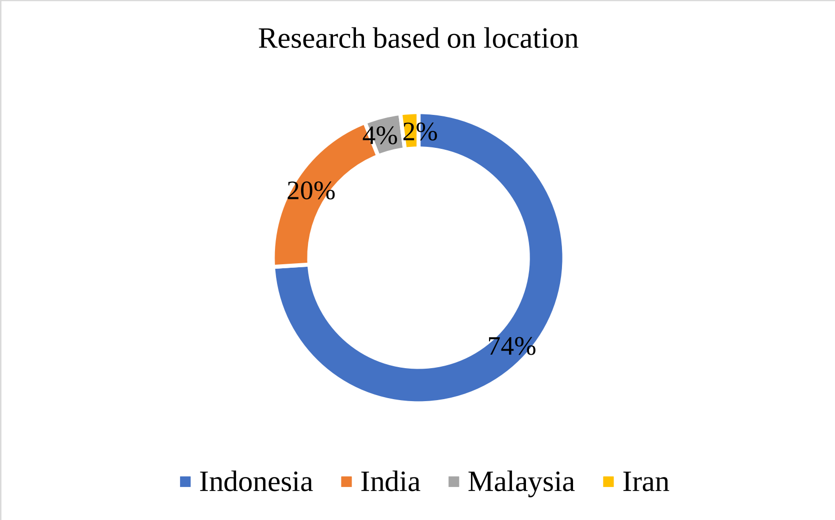


**Figure 4** Classification of scientific articles by research location

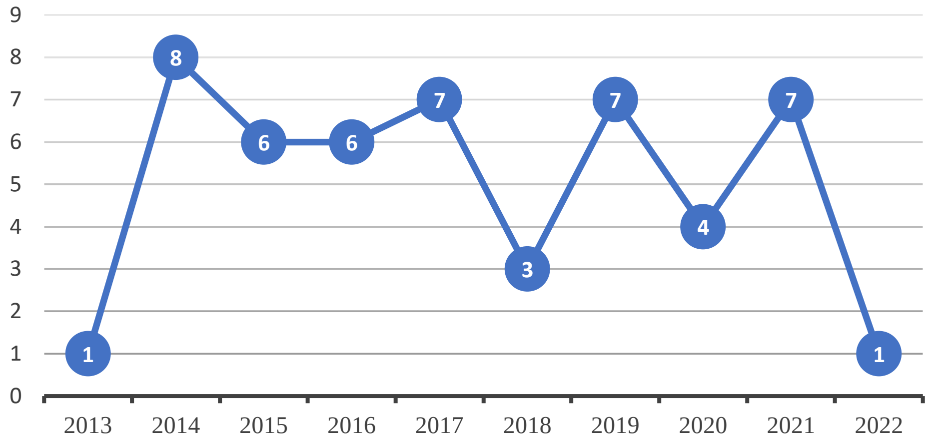


**Figure 5** Scientific articles classification based on publication year

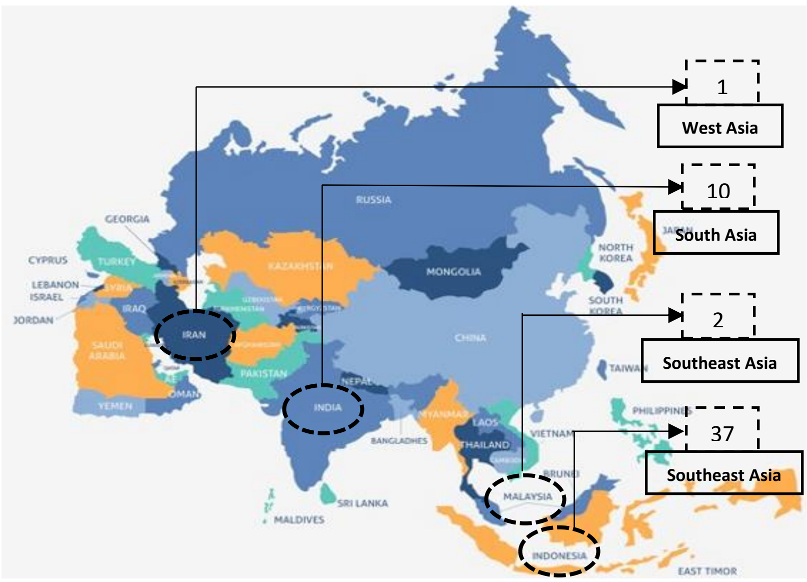


**Figure 6** Scientific articles classification based on publication region

Published articles on Six Sigma have varying specific objectives, but could be generally classified as two main objectives:

- **Six Sigma impact**: Encompasses the impact of Six Sigma implementation on various metrics, such as business performance, quality performance, or even sustainability performance of an organization.
- **Six Sigma development**: Encompasses the development of Six Sigma in various directions, such as Six Sigma scope expansion, Six Sigma integration with another system, or even the means of Six Sigma digitalization.

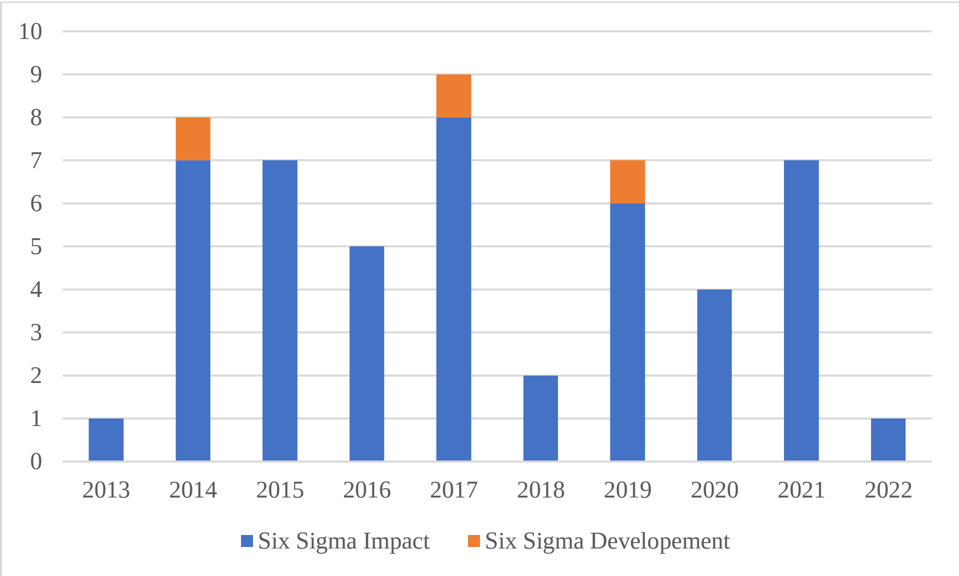


**Figure 7** Scientific articles classification based on the research objective

As seen in Figure 7, this study found that the research on Six Sigma's impact has significant contribution in recent years (47 articles), followed by Six Sigma development (3 articles). The research on Six Sigma impact was almost constantly published every year, while the research on Six Sigma development is generally scarce but still exists in 2014, 2017, and 2019.

### 4.2. Current state-of-the-art of Six Sigma research on the automotive component industry

Six Sigma spread throughout the automotive supply industry through the simple truth that when properly planned and implemented, Six Sigma offers significant benefits that can be realized financially. Six Sigma will not only benefit the customers but will make the industry more efficient, effective and trusted. The stronger the trust in the organization or the product, the more likely that the organization will experience long-term success.

Recent research on the implementation of Six Sigma in the automotive supply industry has yielded many positive results in business development and product quality. Sundana [12] implementing Six Sigma can reduce defective products in the base 2w products with sigma values from 3.83 to 4.10. Sharma [13] increased process capacity in the manufacture of engine crankshafts from (CP) 1.29 to 2.02 and increased process yield (CPK) from 0.32 to 1.45. Raju

[14] reduced defects in steering gear products and Increased the Sigma level from 3.86 to 4.20. Rijanto [15] Quality control in the machining alloy wheel process by increasing the process performance from Cp 1.00 and Cp999k 0.91 to a Cp value of 1.54 and Cpk of 1.54. Danny [16] improved the quality of exhaust products with sigma and DPMO values in 2013 amounted to 3.73σ and 12.879 DPMO. Yorie [17] reduces waste in the OEM spare part production process with sigma level results from waste delays of 1.66σ, induced defect waste of 2.29σ, and motion waste of 2.35 to 3σ. Irawan [18] improved the quality of the assembly of four-wheeled vehicles with a sigma level after the repair results only reached 5.02σ with a target of 6σ. Parwati [19] reduced product defects of the front fender 1pa red met 7 parts in the painting process with a sigma level of 3.25σ. Suseno [20] quality control on line z of the Kijang car production process with a sigma level of 4.7 and a DPMO of 732. Misra [21] reduced the rejection of casting in-house components of the engine block from 7.8% to 1.54 %. Abdul Rahman [22] improved the painting process on vehicle assembly by reducing failures from 10 DPU to 3 DPU. Caesaron [23] reduce defects in the BMW X3 painted body handling process with the BMW X3 painted body handling process still within control limits. Christoper [24] quality control on NXS-001 parts with a result of 23,348.3 DPMO or 3.4σ. Sudarwati [25] reduced flow-out defects in the metal finish in the welding process from 0.005 DPU to 0.002 DPU, and Zahara [26] quality control of rear quarter right APV Arena trim parts with 5563 DPMO or 4σ level. Kawi [27] quality control on disc brake products resulted in a decrease in defective products from 79% to 1.3%. Yadav [28] reduces the resistance of the coupling part by increasing the sigma level from 2.99σ to 3.86σ. Norzaimi [29] reduced product defects in the car audio assembly process from (CP) 0.96 to 2.14. Sucipto [30] reduced the FU 150 cushion seat mount product defect by providing a proposed improvement for the defective product problem on the FU 150 cushion seat mount. Ritme [31] Contamination control of marking waste in the scanning package marking process with throughput increase from 97.64% to 97.80%. Kusumo [32] Waste minimization in the battery manufacturing process reduces waste by increasing the total production from 499,608 to 1,067,886 battery plates. Kaushik [33] reduces wastage and improves the product quality of the seat slide lock nut with a sigma level from 1.59σ to 5.53σ. Noori [34] reducing errors in the grinding process on the machine spindle by implementing Six Sigma and improving organizational management can increase the Sigma level from 0.9σ to 3.0. Imtihan [35] improves the quality of automotive interior body components by increasing the Sigma level from 3.14 to 4.32. Anggarini [36] Reduction of defects and variations in plate thickness Pasta in the battery pasting process Decreased defect value from 4.197% to 0.948%. Swastika Eryan [37] improved the quality of the door lock control knob button product with a sigma result of 3.72 and provided suggestions for improvements to the manufacturing process. Djalmono [38] reduces product defects in the 2dp type part master cylinder with a sigma dai value of 3.581 to 3.812. Widyaningsih [39] minimizes waste in the k 16r mainframe production process with the results of the analysis of the 3 wastes that have the most influence on the production process, namely transportation, excess processing waste and waiting waste. Erizal [40] tested the quality of the front door outer panel of the Toyota Kijang capsule with a sigma value of 3.52σ. Ambar [41] quality control of headrest products by increasing the sigma level from 4.12σ to 4.29. Christy [42]

reduces defective products in wheel products with the calculated DPMO value of 29,326. Gandhi [43] reduces the resistance in the cylinder block by increasing the sigma level from 2.88σ to 3.28σ. Ranade [44] reduced tire manufacturing errors by increasing the sigma level from 1.25 to 1.80. Pathmanaban [45] increased the success rate of ALH4CT machine assembly from 95% to 99%. Nindiani [46] reduced the tailgate trim product defect in the painting process by increasing the sigma value from 2.90 to 3.10. Fitrianto [47] Design for Product Quality Improvement of four-wheeled wheels with a DPMO calculation result of 30,770.03 and an average sigma level of 3.3696σ. Haryanto [48] a reduction in paint defects of dust spots on fuel tank products in the painting process with a Sigma Level result of 3.88 to 4.94. Trimarjoko [49] reduces defects in tire products by increasing the sigma level from 4.48 to 5.02. Maryani [50] process capability improvement in aluminium alloy wheel casting with product performance results from Cp = 0.81 to Cp = 1.4 and an increased level of sigma level = 2.9 to sigma level = 4.0. Setiawan [51] reduces defects in roof panel products in the quality of the packaging process with improvements that can reduce the DPMO value from 33,500 units to 2,050 units and increase the sigma level from 3.33σ to 4.37σ. Supriyati [52] reduces paint defects on automotive parts with a DPMO value of 7619 and a Sigma value of 3.9. Armandhika Utomo [53] decreased flow-out defects and ratio defects in comp jack bracket parts with sigma values from 3.3 to 4.0. Sundaramali [54] an increase in the starter motor shaft assembly from 1.0σ to 2.0σ. Bhargava [55] increased the sigma level from 2.5 to 3.5 reducing process variation in bearing manufacturing. Guleria [56] Reduced gear craft resistance by increasing the sigma level from 4.37 to 4.81. Ariyanto [57] Improved the quality of the work process on motorcycle tires by reducing nylon scrap in motorcycle tires from 5880 PPM to 3454 PPM with a maximum target of 4270 PPM. Sukirno [58] reduces XE 611 exhaust pipe imperfections by increasing the Sigma value from 4.16σ to 4.58σ. Rani [59] improved the quality of plastic painting parts by reducing rejects by 20.58% with the achievement of the sigma value being 4.39. Suda [60] improved the production quality of compression cylinders with the result of a sigma level from 3,5005 to 3,9033. Prasetiyo [61] minimizes waste and increases work efficiency in the production of leaf spring type MSM 2230 with a DPMO value of 14,947,7807 or 3.67σ.

### 4.3. Avenues for future Six Sigma research


**Figure 8** Shifting paradigm in Six Sigma research trend

This study found a classification of the main objectives of the collected articles, namely the large number of studies that found that the current trend of Six Sigma research in the automotive components industry shifted from studying the impact of the application of Six Sigma to its development, such as combination and integration with other concepts such as TPM or TQM.

Although Six sigma has implemented digitalization in recent years, some articles have not implemented six sigma digitalization. The goal of implementing six sigma digitalization can have a greater influence on future business strategies [62]. The importance of digitization in the corporate environment is constantly increasing [62]. Due to the advancing digitization, almost all industrial sectors are affected by its effects [63]. Digitization will have a major impact on future business strategies. One of the affected areas is the implementation of optimization projects. The digital networking of workplaces and automated data acquisition and evaluation also create new opportunities for optimization projects [64]. A proven optimization approach is Six Sigma, which consists of a total of five phases and is used as a globally recognized method for process improvement and error reduction [65]. From the implementation of five-phase digitization, Six Sigma can improve the process and reduce errors to the maximum.


**Figure 9** Future research areas on Six Sigma digitalization

## 5. Conclusion

Using correct inclusion and exclusion criteria, 50 scientific articles were found in journals, books, proceedings, academic social networks, and university websites. All 50 articles are included because they are considered relevant to this study or are excellent examples of how to solve the problem of defective products in the auto replacement industry using a Six Sigma approach. This is because we have a methodology that **as** a result of this research, related topics and questions related to Six Sigma in the auto parts industry were presented. The study found that research on the complete Six Sigma methodology in the automotive components industry is numerous, especially research on the impact of implementing Six Sigma. From these findings, the main avenue for future research can be identified, namely the digitalization of Six Sigma or popularly labelled as Six Sigma Digitalization.

## REFERENCES


[1] N. F. Habidin, S. Mohd Yusof, and N. Mohd Fuzi, "Lean Six Sigma, strategic control systems, and organizational performance for automotive suppliers," *Int. J. Lean Six Sigma*, vol. 7, no. 2, pp. 110–135, 2016, doi: 10.1108/IJLSS-04-2015-0013.

[2] S. Bhat, E. V. Gijo, and N. A. Jnanesh, "Application of Lean Six Sigma methodology in the registration process of a hospital," *Int. J. Product. Perform. Manag.*, vol. 63, no. 5, pp. 613–643, 2014, doi: 10.1108/IJPPM-11-2013-0191.

[3] P. Guleria, A. Pathania, R. K. Shukla, and S. Sharma, "Lean six-sigma: Panacea to reduce rejection in the gear manufacturing industry," in *Materials Today: Proceedings*, 2021, vol. 46, pp. 4040–4046, doi: 10.1016/j.matpr.2021.02.559.

[4] A. Widodo and D. Soediantono, "Benefits of the Six Sigma Method ( DMAIC ) and Implementation Suggestion in the Defense Industry : A Literature Review Manfaat Metode Six Sigma ( DMAIC ) dan Usulan Penerapan Pada Industri Pertahanan : A Literature Review," *J. Soc. Manag. Stud.*, vol. 3, no. 3, pp. 1–12, 2022, [Online]. Available:https://ijosmas.org/index.php/ijosmas/article/view/138%0Ahttps://ijosmas.org/index.php/ijosmas/article/download/138/104.

[5] M. Bhargava and S. Gaur, "Process Improvement Using Six-Sigma (DMAIC Process) in Bearing Manufacturing Industry: A Case Study," in *IOP Conference Series: Materials Science and Engineering*, Jan. 2021, vol. 1017, no. 1, doi: 10.1088/1757-899X/1017/1/012034.

[6] A. Chiarini, "Lean Six Sigma and Industry 4.0 Integration for Operational Excellence: Evidence from Italian manufacturing companies," *Cardiff Univ.*, vol. 59, 2021.

[7] O. Erdil, "Embedding Sustainability in Lean Six Sigma Efforts Embedding Sustainability in Lean Six Sigma Efforts Nadiye O. Erdil Can B. Aktas," 2018. Available: https://digitalcommons.newhaven.edu/mechanicalengineering.

[8] L. B. M. Costa, M. Godinho Filho, L. D. Fredendall, and F. J. Gómez Paredes, "Lean, six sigma and lean six sigma in the food industry: A systematic literature review," *Trends Food Sci. Technol.*, vol. 82, pp. 122–133, 2018, doi: 10.1016/j.tifs.2018.10.002.

[9] P. Bajaj *et al.*, "Coupled Effect of Electronic Medical Record Modifications and Lean Six Sigma Methodology on Rheumatoid Arthritis Disease Activity Measurement and Treat-to-Target Outcomes," *ACR Open Rheumatol.*, vol. 3, no. 3, pp. 164–172, 2021, doi: 10.1002/acr2.11233.

[10] A. Fink, *Conducting Research Literature Reviews: From the Internet to Paper*, Fourth Edi. California: SAGE Publications Inc., 2014.

[11] J. Cruz-Benito, "Systematic Literature Review & Mapping," Salamanca, 2016. doi: 10.5281/zenodo.165773.

[12] S. Sundana and B. Yusuf, "Analisis Kualitas untuk Mengurangi No Good In Process Core Assy 2wv dengan Menggunakan Metode Six Sigma (Studi Kasus di PT. Denso Indonesia)," 2013. Available: http://hdl.handle.net/11617/4111.

[13] G. V. S. S. Sharma and P. S. Rao, "A DMAIC approach for process capability improvement an engine crankshaft manufacturing process," *J. Ind. Eng. Int.*, vol. 10, no. 2, Jun. 2014, doi: 10.1007/s40092-014-0065-7.

[14] M. Raju, G. K. Nithyanandam, and G. Srinivasan, "Defects Reduction in Steering Gear Product using Six Sigma Methodology," vol. 598, pp. 647–651, 2014, doi: 10.4028/www.scientific.net/AMM.598.647.

[15] O. A. W. Rijanto, "Analisis Pengendalian Mutu Proses Machining Alloy Wheel Menggunakan Metode Six Sigma," *J. Ilm. Tek. Ind.*, vol. 13, no. 2, pp. 177–186, 2014.

[16] L. Danny Dharmawan Dan Yurida Ekawati, "Peningkatan Kualitas Knalpot Pada Pt Fajar Indah Menggunakan Metode Six Sigma," 2014, doi: https://doi.org/10.22219/JTIUMM.Vol15.No2.112-123

[17] B. Yorie and M. Putro, “Pendekatan Lean Six Sigma Dan Metode Weighted Product Untuk Mengurangi Waste Pada Proses Produksi Spare Part Oem Di Pt. Sinar Agung Selalu Sukses,” 2014. Available: https://core.ac.uk/download/pdf/35373745.pdf.

[18] S. Irawan, “Pendekatan Metode Six Sixma (Dmaic) Dan Proses Audit (Cppp) Untuk Peningkatan Kualitas Di Pt. Igp,” Jurnal PASTI Volume VIII No 3, 411 – 422, 2014.

[19] C. I. Parwati, “Minimasi Ng Bintik Pada Proses Pengecatan Part Front Fender 1pa Red Met 7 Dengan Pendekatan Six Sigma Di Pt. Abc,” 2014. Available: http://hdl.handle.net/11617/4629

[20] R. Suseno, “Analisis Pengendalian Kualitas Six Sigma Dengan Metode Define, Measure, Analyze, Improve, Control (Dmaic) Terhadap Lini Z Proses Produksi Mobil Kijang Di Pt. Toyota Motor Manufacturing Indonesia,” *Suseno*, vol. 8, no. 1, pp. 35–44, 2014, [Online]. Available: https://jurnal.umj.ac.id/index.php/jisi/article/view/8537.

[21] R. K. Misra and A. Chauhan, “Six Sigma approach for reducing rejection of in-house cast component,” 2015, doi: https://doi.org/10.1504/IJSSCA.2015.074964.

[22] M. Abdul Rahman, A. K. M. Mohiuddin, and H. Abdullah, “Painting Process Improvement through Six Sigma Approach in a Malaysian Vehicle Assembly Company,” *Adv. Mater. Res.*, vol. 1115, pp. 596–600, Jul. 2015, doi: 10.4028/www.scientific.net/amr.1115.596.

[23] D. Caesaron, “Penerapan Metode Six Sigma Dengan Pendekatan Dmaic Pada Proses Handling Painted Body Bmw X3 (Studi Kasus: Pt. Tjahja Sakti Motor),” Jurnal PASTI Volume IX No 3, 248 – 256, 2015.

[24] C. Christoper and H. Suliantoro, “Analisa Pengendalian Kualitas dengan Menggunakan Metode Six Sigma untuk Part NXS-001 pada PT Inti Pantja Press Industri,” *Ind. Eng. Online J.*, vol. 4, no. 4, 2015.

[25] W. Sudarwati and A. Wijaya, “Penggunaan Metode Six Sigma Dalam Upaya Menurunkan Cacat Mengalir ( Flow Out ) Ke Metal Finish ( Dept Body Welding ) Di Pt.Adm Press-Plant,” *JISI J. Integr. Sist. Ind. Vol.*, vol. 2, no. 2, 2015, doi: 10.24853/jisi.4.1.pp-pp.

[26] F. Zahara, “Pengendalian Kualitas Part Trim Rear Quarter Right APV Arena dengan Menggunakan Metode Six Sigma di PT. Suzuki Indomobil Motor,” *J. Optimasi Sist. Ind.*, vol. 13, no. 1, p. 486, 2016, doi: 10.25077/josi.v13.n1.p486-502.2014.

[27] Kawi, Rony , “Penerapan Six Sigma Sebagai Alat Bantu Statistik Untuk Pengendalian Kualitas Produk Disk Brake,” 2015. Available: http://repository.ubharajaya.ac.id/id/eprint/6639

[28] A. Yadav and V. K. Sukhwani, “Quality Improvement by using Six Sigma DMAIC in an Industry,” vol. 6, no. 6, pp. 41–46, 2016. Available: http://inpressco.com/category/ijcet

[29] M. Norzaimi and C. Ani, “Solving Quality Issues in Automotive Component Manufacturing Environment by utilizing Six Sigma DMAIC Approach and Quality tools,” pp. 1986–1997, 2016. Available: http://ieomsociety.org/ieom_2016/pdfs/586.pdf.

[30] F. Sucipto, M. Y. Lubis, and M. Iqbal, “Minimize Penyebab Produk Cacat Pada Workstation Production Di Pt. Xyz Dengan Pendekatan Metode Six Sigma,” *eProceedings Eng.*, vol. 3, no. 1, 2016.

[31] I. Ritme, P. Siallagan, D. Redantan, and Z. Arifin, “Pengendalian Reject Contamination On Marking Pada Proses Mark Scan Pack (Msp) Dengan Pendekatan Six Sigma (Studi Kasus Di Pt. Infineon Technologies Batam) The Control Of Reject Contamination On Marking Of Mark Scan Pack Process (Msp) By Six Sigma Approach (Case Study in PT. Infineon Technologies Batam),” *PROFISIENSI*, vol. 4, no. 1, pp. 37–46, 2016.

[32] V. B. Kusumo, “Peningkatan Laju Produksi Dengan Meminimasi Waste Menggunakan Metode Lean Six Sigma (Studi Kasus: PT. Indobatt Industri Permai),” 2016. [Online]. Available: www.tcpdf.org.

[33] P. Kaushik and S. Kumar, “An application of six sigma for SMEs: A case study,” *Manag.*

*Sci. Lett.*, vol. 7, no. 3, pp. 145–152, 2017, doi: 10.5267/j.msl.2016.12.002.

[34] B. Noori and M. Latifi, "Development of Six Sigma methodology to improve grinding processes: A change management approach," *Int. J. Lean Six Sigma*, vol. 9, no. 1, pp. 50–63, 2017, doi: 10.1108/IJLSS-11-2016-0074.

[35] M. Imtihan, "Redesign Alat Tambahan Pada Mesin Produksi Komponen Otomotif Body Inner Dalam Meningkatkan Kualitas Melalui Strategi Dmaic," *JIEM*, vol. 2, no. 2, 2017.

[36] L. Anggarini, "Reduksi Defect Dan Variasi Tebal Plat Berpasta Pada Proses Pasting Dengan Metode Lean Six Sigma (Studi Kasus : Pt. Indobatt Industri Permai)," 2017. Available: http://repository.its.ac.id/id/eprint/3261.

[37] N. Swastika Eryan, "Quality Control Untuk Produksi Spare Part Pada Pt. Ypti Divisi Plastic Injection Menggunakan Metode Six Sigma," 2017. Available: http://hdl.handle.net/11617/8629.

[38] W. Djalmono Putro, A. Slamet, A. Maulana, "Perbaikan Kualitas Proses Produksi Dengan Metode Six Sigma Untuk Mengurangi Cacat Produk Pada Partmaster Cylinder Tipe 2dp Di Departemenpainting Pt. Chemco Harapan Nusantara Cikarang," 2017, doi: http://dx.doi.org/10.32497/rm.v12i2.1054.

[39] N. Widyaningsih, "Usulan Penerapan Metode Lean Six Sigma Untuk Meminimasi Waste pada Proses Produksi Mainframe K 16R di PT. Pamindo Tiga T." 2019, Available: http://repository.unugha.ac.id/id/eprint/531.

[40] D. P. T. X. Erizal, "Analisis Kualitas Produk Panel Front Door Outer Toyota Kijang Kapsul Dengan Metode Six Sigma," 2017. Available: https://ejournal.istn.ac.id/presisi/article/view/126.

[41] J. Ekonomi, M. & Bisnis, I. Ambar, S. Dan, and M. Bernik, "Penggunaan New And Old Seven Tools Dalam Penerapan Six Sigma Pada Pengendalian Kualitas Produk Stay Headrest," *J. Ekon. Manaj. Bisnis*, vol. 19, no. 1, 2018.

[42] E. Christy, "Upaya Peningkatan Kualitas Wheel Dengan Metode Six Sigma Di PT. Meshindo Alloy Wheel," *J. Rekayasa dan Manaj. Sist. Ind.*, vol. 6, no. 7, pp. 1472–1483, 2018, [Online]. Available: www.tcpdf.org.

[43] S. K. Gandhi, A. Sachdeva, and A. Gupta, "Reduction of rejection of cylinder blocks in a casting unit: A six sigma DMAIC perspective," *J. Proj. Manag.*, pp. 81–96, 2019, doi: 10.5267/j.jpm.2019.1.002.

[44] P. B. Ranade, P. J. Ugale Mechanical Department, and S. C. Pagare, "Defect Analysis and Implementation of DMAIC Methodology for Defect Reduction in Tyre Manufacturing," *Int. J. Innov. Res. Appl. Sci. Eng.*, vol. 3, no. 5, pp. 479–482, 2019, doi: 10.29027/IJIRASE.v3.i5.2019.

[45] P. Pathmanaban, "Six Sigma Methodologies for Increasing the First Pass Rate of Engines in Manufacturing," *J. Adv. Res. Qual. Control Manag.*, vol. 04, no. 01, pp. 24–30, Aug. 2019, doi: 10.24321/2582.3280.201904.

[46] A. Nindiani, R. Nursikin, A. Kustia, T. Sertiadi, W. Ni, and W. Puji, "Penurunan Cacat Produk Garnish-Assembly Tailgate Di Perusahaan Otomotif Melalui Pendekatan Metode Dmaic," *Ind. Xplore*, vol. 04, no. 01, 2019.

[47] D. Fitrianto, "Disain Perbaikan Kualitas Produk dengan Pendekatan Six Sigma di PT. Prima Alloy Steel Universal," 2019, doi: https://doi.org/10.36040/seniati.v5i2.923.

[48] E. Haryanto, "Analisa Penurunan Cacat (Defect) Cat Bintik Debu Dengan Metodologi Six Sigma Pada Proses Painting Produk Fuel Tank Di Pt. Sso Tangerang," 2019, doi: https://dx.doi.org/10.22441/pasti.2019.v13i3.009.

[49] A. Trimarjoko, D. S. Saroso, H. H. Purba, S. Hasibuan, C. Jaqin, and S. Aisyah, "Integration of nominal group technique, Shainin system and DMAIC methods to reduce defective products: A case study of the tire manufacturing industry in Indonesia," *Manag. Sci. Lett.*, vol. 9, no. Special Issue 13, pp. 2421–2432, 2019, doi:

10.5267/j.msl.2019.7.013.

[50] E. Maryani, H. H. Purba, and S. Sunadi, "Process Capability Improvement Through DMAIC Method for Aluminium Alloy Wheels Casting," *J. Ind. Eng. Manag. Res.*, vol. 1, no. 4, pp. 19–26, 2020.

[51] I. Setiawan and S. Setiawan, "Defect reduction of roof panel part in the export delivery process using the DMAIC method: a case study," *J. Sist. dan Manaj. Ind.*, vol. 4, no. 2, pp. 108–116, Dec. 2020, doi: 10.30656/jsmi.v4i2.2775.

[52] Supriyati, "Analisis Cacat Painting Pada Komponen Automotive Dengan Pendekatan Dmaic," P. 2020, 2020.

[53] D. Armandhika Utomo and E. Rimawan, "Menggunakan Metode Lean Six Sigma-Dmaic," 2020.

[54] Sundaramali, "Application of DMAIC to Reduce the Rejection Rate of Starter Motor Shaft Assembly in the Automobile Industry: A Case Study," *Int. J. Ind. Eng. Prod. Res.*, vol. 32, no. 3, 2021, doi: 10.22068/ijiepr.32.3.1.

[55] M. Bhargava and S. Gaur, "Process Improvement Using Six-Sigma (DMAIC Process) in Bearing Manufacturing Industry: A Case Study," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1017, no. 1, pp. 0–14, 2021, doi: 10.1088/1757-899X/1017/1/012034.

[56] P. Guleria, A. Pathania, R. Kumar, and S. Sharma, "Materials Today : Proceedings Lean six-sigma : Panacea to reduce rejection in the gear manufacturing industry," *Mater. Today Proc.*, no. xxxx, 2021, doi: 10.1016/j.matpr.2021.02.559.

[57] B. Ariyanto, P. Gajah Tunggal, T. -Indonesia, S. Sudarto, and T. D. Sofianti, "Improving Work in Process Quality (Bias Cutting Process) by Using Poka-Yoke and Define Measure Analysis Improve and Control (DMAIC) Method in Leading Motorcycle Tire Manufacturing."

[58] E. Sukirno, J. Prasetyo, R. Rosma, and M. Hayu Raras Sita Rukmika Sari, "Implementasi Metode Six Sigma Dmaic Untuk Mengurangi Defect Pipe Exhaust Xe 611," *JAPTI J. Apl. Ilmu Tek. Ind.*, vol. 2, no. 2, pp. 10–18, 2021, [Online]. Available: www.journal.univetbantara.ac.id/index.php/japti.

[59] A. M. Rani and Y. R. Wahyudi, "Peningkatan Kualitas Part Painting Plastik Menggunakan Metode Six Sigma Di PT XYZ Jakarta," *Jisi J. Integr. Sist. Ind.*, vol. 8, no. 1, pp. 35–44, 2021, doi: 10.24853/jisi.8.1.36-44.

[60] J. D. Suda, "Aplikasi Metode Six Sigma Untuk Meningkatkan Kualitas Produksi Silinder Kompresi," 2021.

[61] D. Prasetyo, "Pendekatan Lean Six Sigma Sebagai Upaya Meminimalkan Waste Dan Meningkatkan Efisiensi Kerja Pada Produksi Leaf Spring Type MSM 2230 (Studi Kasus PT. Indospring Tbk)," 2022, doi: 10.350587/Matrik.

[62] J. Ohlig, P. Poetters, and B. Leyendecker, "The Impact of Digitalization on the Define Phase of the Six Sigma Methodology," *Proc. Int. Conf. Ind. Eng. Oper. Manag.*, pp. 232–242, 2021.

[63] A. Lipsmeier, A. Kühn, R. Joppen, and R. Dumitrescu, "Process for the development of a digital strategy," *Procedia CIRP*, vol. 88, pp. 173–178, 2020, doi: 10.1016/j.procir.2020.05.031.

[64] V. L. Da Silva, J. L. Kovaleski, R. N. Pagani, J. D. M. Silva, and A. Corsi, "Implementation of Industry 4.0 concept in companies: empirical evidence," *Int. J. Comput. Integr. Manuf.*, vol. 33, no. 4, pp. 325–342, 2020, doi: 10.1080/0951192X.2019.1699258.

[65] S. Xiao, Y. Li, M. Rotaru, and J. K. Sykulski, "Six sigma quality approach to robust optimization," *IEEE Trans. Magn.*, vol. 51, no. 3, pp. 1–4, 2015, doi: 10.1109/TMAG.2014.2360435.