Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5, 701-707
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i5.1734

Analysis and implementation of the dmaic six sigma method as an effort to control weaving fabric production defects: Industrial textile case study

Evan Nugraha[1*], Rini Mulyani Sari[2], Asep Kurniawan[3], Darfial Guslan[4]
[1,2,3,4]Jenderal Achmad Yani University, Indonesia; noe.rievan@gmail.com (E.N)
[4]Logistics and Business Internasional University, Indonesia.

Abstract: Defective items are those that are produced during the manufacturing process but do not meet the imposed quality standards. These items can be repaired economically if certain costs are covered, which must be less than the post-repair selling value of the product. Semi-finished textiles are produced by the research institute. There are still issues with the production of semi-finished cloth. As a result, the researcher attempted to control and evaluate flaws in the production of semi-finished fabrics by combining the DMAIC approach (Define, Measure, Evaluate, Improve, and Control) with the six-sigma method. A million production operations have a 3.3% Defect Per Million Opportunities (DPMO), or a sigma level value of 2,625 or 133,219 probability of damage, according to the study's findings. There are two types of production-related damage: non-process and process. After one month of implementing and evaluating improvements, there has been a gradual improvement in all production processes, with the most recent calculation for June 2024 yielding a sigma value of 3.51.

Keywords: *DMAIC, Fishbone, FMEA, Six Sigma.*

1. Introduction

Industrial rivalry is today facing more challenging hurdles in both production and services. Over time, customer wants for goods and services have been identified not only in terms of quantity but also of quality. As a result of this occurrence, making quality the primary approach will provide a competitive edge in the market's dominance competition [1][2]. Companies must begin organizing strategies to develop both the company's business processes and the quality of the products produced now and in the future. In the age of Industry 4.0 and Society 5.0, a company must implement new methods in order to compete with other businesses. One of them is that businesses must be able to use quality management systems like six sigma and technology that are integrated in cyberspace and the real world and are currently widely used by multinational corporations [3]; [4]; [5]. Not every business can reach excellent quality. There are numerous obstacles associated with high-quality items that must be applied and managed by the firm in order to improve and sustain the company's continuity [6]; [7]. Furthermore, companies that have received the ISO 9001 certification for quality management systems. To survive in the international market, the company must maintain the quality of its products [8]; [9]; [10]; [11]. In Indonesia, there are many manufacturing companies, particularly those that produce textile fabrics. One of them is a company that manufactures semi-finished or raw cloth. PT. Dwi Mandiri is a textile firm that weaves cloth. So far, there are still faults or discrepancies in the weaving process for manufacturing cloth [12]; [13]; [14]; [15]. The following defects can occur during the weaving process when making cloth: 1). A rare weft is a defect caused by a problem with the density of the weft; 2). Rare warp is a flaw caused by a problem with warp thread density; 3). Filling stretches are defects caused by incorrect weft thread installation; 4). Warp streaks are flaws caused by the mixing of different types of warp threads in the fabric; 5). Floating ends, a flaw caused by an error in

* Correspondence: noe.rievan@gmail.com

the threading of the warp that is not woven; 6). Ring temple defects occur when the needles in the ring temple do not rotate, causing holes in the fabric's edges. To overcome these issues in the company, defect analysis using the six sigma method can be performed as a business process improvement that aims to find and reduce the factors that cause defects and errors, reduce cycle time and operating costs, increase productivity, meet customer needs and lean thinking for six sigma [16]; [17]; [18]; [19]; [1].

2. Research Method

To determine the level of defects that occurred in the company, data was collected through observation and interviews with the head of production. The data obtained were woven fabric production results from January 2024 to June 2024.

Stages of Analysis

This study's analysis stages are as follows [20]; [21]; [22]:

1. Determine the problem phase (define) using six sigma by observation to determine quality activity targets and collect types of production defect data in the first six months of 2024.
2. The second stage of this research is the collection of primary data from January 2024 to June 2024 with the goal of determining the sigma value of quality during that time period.
3. The third stage involves analyzing data on the number of defects and using cause and effect diagrams to determine the root cause of the problem and potential quality improvements.
4. The fourth stage is improved, which is the stage in which the solution from the analysis is implemented to eliminate the causes of existing problems using Failure Mode and Effect Analysis (FMEA) with three indications as Occurrence (O), Severity (S), Detectability (D).

The fifth stage is control, which is concerned with maintaining changes made during the improve phase in order to monitor, improve, ensure continued success, develop control plans, and update renewal documents. Level sigma methods are used in this fifth stage [23]; [24]; [25]; [26]; [27][28]; [29]; [30].

3. Results

In accordance with best practices for implementing lean management, data processing is carried out by following the steps of the DMAIC pattern [31]; [32]; [33]. The goal of this pattern is to make it easier to apply the method in the production process. Those steps can be seen below:

3.1. Define

Based on the findings of the company's research and identification kind of type reject dominan as Warp feed are sparse (WFS), Warp threads are sparse (WTS), Filling streaks (FS), Warp streaks (WS), Floanting ends (FE), Reject ring temple (RRT). Table 1 shows examples of these types of flaws.

Tabel 1.
Period defect production results data January 2024 - June 2024 (in a thousand).

No	Month	Production	Type of Reject						Production total
			WFS	WTS	FE	WS	FE	RRT	
1	January	3.728	128	170	153	139	126	116	4.563
2	February	3.983	142	153	134	185	157	198	4.867
3	March	3.898	132	134	153	153	125	124	4.721
4	April	3.876	163	152	172	156	183	193	4.898
5	Mei	3.759	127	183	124	138	172	126	4.633
6	June	3.890	182	127	126	153	129	137	4.748

3.1. Measure

The company measures the value of the production quality characteristics based on the company's defects per million opportunities (DPMO) and analyzes the sigma level during the Measure stage.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5: 701-707, 2024
DOI: 10.55214/25768484.v8i5.1734

1. Calculating DPO (Defect Per Opportunities):

$$DPU = \frac{Total\ Production\ Defect}{Total\ Production}\ x\ Critical\ to\ Quality$$

2. Calculating DPMO (Defects Per Million Opportunities)

$$DPU = \frac{Total\ Production\ Defect\ x\ 1.000.000}{CTQ\ x\ Total\ Production}$$

So that the overall DPO and DPMO results are as follows:

Table 2.
DPO and DPMO calculation data results.

Period	Total products	Defective produk	CTQ	(DPO)	DPMO	Sigma levels
January	4.563.061	834.870	6	0,030	30493,784	3,47
February	4.867.914	972.218	6	0,032	32694,672	3,34
March	4.721.463	822.519	6	0,029	29034,750	3,40
April	4.898.789	1.022.194	6	0,034	34777,098	3,31
Mei	4.633.428	873.539	6	0,031	31421,624	3,46
June	4.748.583	857.628	6	0,030	30101,190	3,48
					Total sigma levels	3,36

According to the DPMO, the production section had a sigma level of 3.3 in April and September, or was in a condition of 3.4 sigma, with a possible damage of 972,218 in April and 1,022,194 in October for a million production processes. If production processes were not improved to reduce the level of product damage produced in each production process, this would undoubtedly be a loss for the company. The sigma level has been at an average of 3.36 for the past 6 months, which is still far from sigma level 6.

3.1. Analyze

Cause and effect diagrams are used to visualize a variety of possibilities that lead to problems in the process. The cause-and-effect control chart in the image below shows information obtained from job interviews about the things that cause these problems.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5: 701-707, 2024
DOI: 10.55214/25768484.v8i5.1734

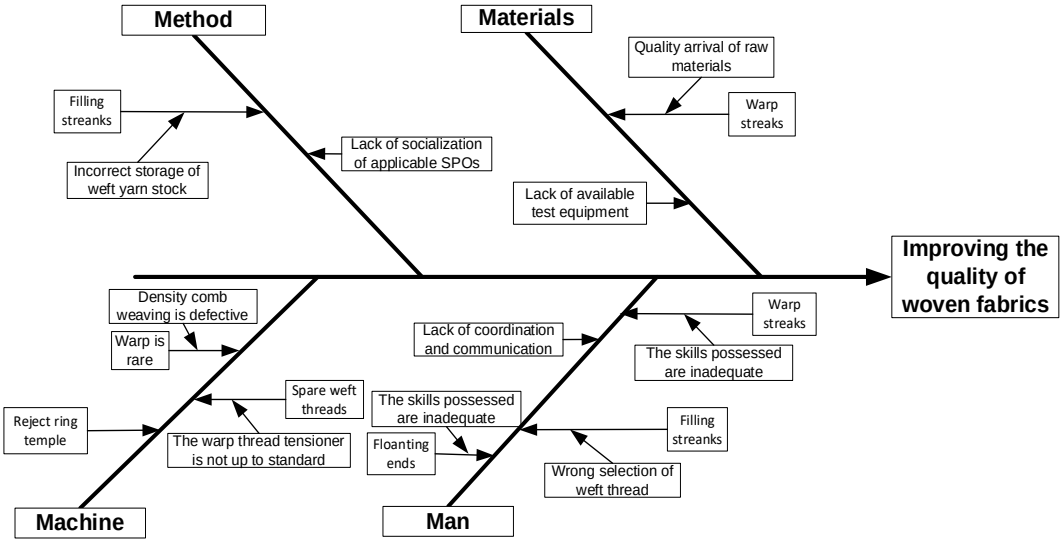

Figure 1.
Fishbone analysis.

Figure 1 shows that defects in raw fabric at the company are caused by human factors, such as the occurrence of floanting ends caused by the process of weaving the warp that is not woven and insufficient skills, filling streaks caused by improper installation of the weft thread by the operator on the weaving machine, and warp streaks caused by differences in thread type. The warp is mixed into the fabric type. For example, sample ring defects are caused by the thread getting dirty on the sample ring roll, causing the sample ring to jam and not rotate, and rare weft is caused by non-standard warp thread tensioners, which causes the density of the weft to increase.

3.3. Improve

After determining the causes of damage and the types of product damage, a recommendation or proposal for general corrective action is prepared in an effort to reduce the level of product damage. An analysis of the problem was performed using the FMEA (failure mode and effect analysis method) to determine the critical level of the fishbone diagram.

Table 3.
Failure mode and effect analysis for identification of problems.

No factors	Before implementation of six sigma				After implementation of six sigma			
	O	S	D	RPN	O	S	D	RPN
1. Man	8	8	7	448	7	6	6	252
	8	9	8	576	7	6	7	294
	8	8	8	512	8	7	7	392
	8	8	7	448	7	6	7	294
2. Material	7	7	7	343	6	7	7	294
	7	8	7	392	6	6	7	252
3. Machine	7	6	7	294	6	6	6	216
	6	7	7	294	6	6	7	252
4. Method	8	7	8	448	6	7	7	294
	8	7	7	392	7	7	7	343

The following are the results of the FMEA analysis:

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5: 701-707, 2024
DOI: 10.55214/25768484.v8i5.1734

1. Human Factor
   a. Disseminate the results of the SOP regarding procedures for cutting warp on weaving combs, conduct training to improve skills and accuracy in cutting quality, and re-inspect the work of bow operators.
   b. Carry out failing identification of the weft raw material storage rack, provide clear identity for jumbo weft regarding weft yarn specifications, and socialize the results of the SOP regarding procedures for processing jumbo weft products to increase skills and accuracy regarding the quality of jumbo weft products and failing identification of raw yarn materials. warp, provide a clear identity to the warp thread cylinder in terms of warp thread specifications, and disseminate the results of the SOP in terms of procedures for working on beaming products for warp threads in order to increase skills and accuracy in product quality.
   c. Providing regular training on work systems, skills and knowledge of different types of raw materials, products, and handling production machines. Workplace discipline should be improved.
2. Materials Faktor
   a. Coordination with suppliers to double-check before sending to the company, as well as socialization of SOPs.
   b. Carrying out raw yarn material identity failure, providing clear identity for cones, cylinders, jumbo weft yarns to cones and beams of warp yarn in terms of yarn specifications.
   c. It is proposed to equip the raw material testing laboratory with testing equipment and to disseminate the results of the SOP, as well as to perform double-checking using cheek sheets to check the quality of the warp and weft yarns in order to anticipate errors in mixing other types of yarn with the specifications of the fabric being produced.
3. Machine Faktor
   a. Disseminate the results of the SOP regarding preventive maintenance, every machine setting in beamsteel implementation, the sample ring must be cleaned from the remains of previous production threads, checked again after the beamsteel process is complete using a machine condition report cheek sheet, and the technician must conduct training to improve skills and accuracy regarding quality and machine condition.
   b. Before running the loom to produce cloth, the machine's condition is re-checked, and samples of fabric produced by the machine are taken to check the quality of the fabric, including comb density, warp and weft thread quality, to anticipate errors in mixing other types of thread with the specifications of the fabric being produced.
4. Method Faktor
   a. Carry out identity failure of the weft yarn raw material storage rack, providing clear identity to all types of yarn specifications.

Disseminate the SOP results regarding procedures for providing identity to specifications for all types of thread in both the raw material and production process warehouses.

3.4. Control

Following the implementation of improvements, the next step is to implement control with a better strategy for repairing defects in the manufacturing process. All of these issues arise as a result of human factors, materials, machines, and methods [34]; [35]; [36]. As a result, overcoming this type of reject must be done at the company. The achievement of the sigma level each period serves as the reference for the control chart. At this stage, a control chart is created with the goal of determining the upper and lower limits of control so that it can be determined whether the company's rejects are within reasonable limits or not.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 5: 701-707, 2024
DOI: 10.55214/25768484.v8i5.1734

4. Conclusions

Based on the results of the company's analysis of production defects using the six-sigma method, it has a sigma level of 3.36 or is in a 3-sigma condition with a probability of damage of 133,219 for a million production processes or 13.3% Defect Per Million Opportunities (DPMO) in the 2024 period. The damage caused during production is then divided into two categories: reject process and reject nonprocess. Reject Process produces the most product damage, accounting for 57.1% of total damage, while Reject Nonprocess produces as much as 42.9%. This is caused by machine and human factors such as a lack of supervision of production employees, regular machine maintenance and repair, and the selection of high-quality raw materials for use in the manufacturing process. After one month of implementing and evaluating improvements, there has been a gradual increase in all production processes, with a sigma value of 3.51 obtained from the most recent calculation for June 2024.

5. Funding

Based on the results of the Company's six sigma analysis of production defects, it has a sigma level of 3.36 or is in a 3-sigma condition in 2024, with a probability of damage of 133,219 for a million production processes or 13.3% Defect Per Million Opportunities (DPMO). The damage caused during production is then divided into two categories: reject process and reject nonprocess. Reject Process produces the most product damage, accounting for 57.1% of total damage, while Reject Nonprocess produces as much as 42.9%. This is caused by machine and human factors such as a lack of supervision of production employees, regular machine maintenance and repair, and the selection of high-quality raw materials for use in the manufacturing process.

References

[1] G. Bilgin Turna, "Application of Lean Six Sigma for yield improvement in the stainless steel industry: a recipe from Türkiye," *Int. J. Lean Six Sigma*, vol. 14, no. 3, pp. 534–554, Jan. 2023, doi: 10.1108/IJLSS-02-2022-0049.

[2] M. A. Pratama, C. N. Rosyidi, and E. Pujiyanto, "Two stages optimization model on make or buy analysis and quality improvement considering learning and forgetting curve," *J. Ind. Eng. Manag.*, vol. 11, no. 4, pp. 794–813, 2018, doi: 10.3926/jiem.2615.

[3] C. Hernandez, J. J. Lopez, R. Melnyc, M. Friedman, and H. Gitlow, "Six Sigma for home health care: Applying theories & methodologies," *Int. J. Healthc. Manag.*, vol. 14, no. 1, pp. 175–182, Jan. 2021, doi: 10.1080/20479700.2019.1621021.

[4] I. C. Ng and P. S. Hempel, "Organisational culture and the implementation of Six Sigma in Southern China," *Total Qual. Manag. Bus. Excell.*, vol. 31, no. 1–2, pp. 82–98, Jan. 2020, doi: 10.1080/14783363.2017.1413343.

[5] M. R. Vendrame Takao, J. Woldt, and I. B. da Silva, "Six Sigma methodology advantages for small- and medium-sized enterprises: A case study in the plumbing industry in the United States," *Adv. Mech. Eng.*, vol. 9, no. 10, pp. 1–10, 2017, doi: 10.1177/1687814017733248.

[6] L. Ayach, A. Anouar, and M. Bouzziri, "Quality cost management in moroccan industrial companies: Empirical study," *J. Ind. Eng. Manag.*, vol. 12, no. 1, pp. 97–114, 2019, doi: 10.3926/jiem.2749.

[7] H. Tannady and Y. Maimury, "Increasing the efficiency and productivity in the production of low voltage switchboard using resource constrained project scheduling," *J. Ind. Eng. Manag.*, vol. 11, no. 1, pp. 1–33, 2018, doi: 10.3926/jiem.2228.

[8] R. Almanaeseh *et al.*, "The effect of cloud computing on the quality of financial statements: The mediating role of internal control system," *Int. J. Data Netw. Sci.*, vol. 8, no. 4, pp. 2627–2638, 2024, doi: 10.5267/j.ijdns.2024.4.015.

[9] P. M. Ali, R. Raju, A. M. Raja, M. S. Ali, and S. S. Raja, "Influence of organization profile on the application of quality management tools and techniques," *Manag. Sci. Lett.*, vol. 14, no. 2, pp. 87–92, 2024, doi: 10.5267/j.msl.2023.10.001.

[10] J. Thakkar and S. Vinodh, "Guest editorial," *Int. J. Lean Six Sigma*, vol. 12, no. 1, pp. 1–2, 2021, doi: 10.1108/IJLSS-02-2021-205.

[11] U. Awan, A. Kraslawski, and J. Huiskonen, "The impact of relational governance on performance improvement in export manufacturing firms," *J. Ind. Eng. Manag.*, vol. 11, no. 3, pp. 349–370, 2018, doi: 10.3926/jiem.2558.

[12] L. Paipa-Galeano, C. A. Bernal-Torres, L. M. Agudelo-Otalora, Y. Jarrah-Nezhad, and H. A. González-Blanco, "Key lessons to sustain continuous improvement: A case study of four companies," *J. Ind. Eng. Manag.*, vol. 13, no. 1, pp.

195–211, 2020, doi: 10.3926/jiem.2973.
[13] M. Stanojeska, R. Minovski, and B. Jovanoski, "Top management role in improving the state of QMS under the influence of employee's involvement: Best practice from the food processing industry," *J. Ind. Eng. Manag.*, vol. 13, no. 1, pp. 93–119, 2020, doi: 10.3926/jiem.3031.
[14] M. Taherimashhadi and I. Ribas, "A model to align organizational culture to lean culture," *J. Ind. Eng. Manag.*, vol. 11, no. 2, pp. 207–221, 2018, doi: 10.3926/jiem.2511.
[15] X. Liu and B. Wang, "Joint optimization of economic production quantity and preventive maintenance with considering multi-products and reserve time," *J. Ind. Eng. Manag.*, vol. 10, no. 3, pp. 431–443, 2017, doi: 10.3926/jiem.2270.
[16] J. E. Ortiz-Porras, A. M. Bancovich-Erquínigo, T. C. Candia-Chávez, L. M. Huayanay-Palma, R. K. Moore-Torres, and O. R. T. Gomez, "Green Lean Six Sigma Model for Waste Reduction of Raw Material in a Nectar Manufacturing Company of Lima, Peru," *J. Ind. Eng. Manag.*, vol. 16, no. 2, pp. 169–185, 2023, doi: 10.3926/jiem.4916.
[17] H. Gitlow, "Deming-based Lean Six Sigma stewardship," *Qual. Manag. J.*, vol. 30, no. 3, pp. 202–208, Jul. 2023, doi: 10.1080/10686967.2023.2211286.
[18] H. M. M. Silva, R. M. Vanalle, W. C. Lucato, and F. A. Calarge, "Relevance of Barriers for Six Sigma Implementation in Industrial Organizations," *Lat. Am. Bus. Rev.*, vol. 24, no. 3, pp. 207–241, Jul. 2023, doi: 10.1080/10978526.2023.2222080.
[19] F. Pakdil, G. F. F. Can, and P. Toktaş, "Guest editorial: Lean Six Sigma developments in Türkiye," *Int. J. Lean Six Sigma*, vol. 14, no. 3, pp. 517–519, 2023, doi: 10.1108/IJLSS-05-2023-231.
[20] A. A. Abdallah, "Simulated Six Sigma: A multi response optimization," *Qual. Eng.*, vol. 32, no. 4, pp. 583–594, Oct. 2020, doi: 10.1080/08982112.2019.1694151.
[21] C.-C. Wei and Y.-L. Cheng, "Six Sigma project selection using fuzzy multiple attribute decision-making method," *Total Qual. Manag. Bus. Excell.*, vol. 31, no. 11–12, pp. 1266–1289, Aug. 2020, doi: 10.1080/14783363.2018.1473029.
[22] A. Deithorn and J. V Kovach, "Achieving aggressive goals through Lean Six Sigma: A case study to improve revenue collection," *Qual. Eng.*, vol. 30, no. 3, pp. 371–388, Jul. 2018, doi: 10.1080/08982112.2018.1437448.
[23] M. Uluskan, "Enhancing Six Sigma Understanding: Insights into Various Dimensions and Aspects of Six Sigma," *Eng. Manag. J.*, vol. 34, no. 1, pp. 99–128, Jan. 2022, doi: 10.1080/10429247.2020.1852806.
[24] A. Niñerola, M.-V. Sánchez-Rebull, and A.-B. Hernández-Lara, "Mapping the field: relational study on Six Sigma," *Total Qual. Manag. Bus. Excell.*, vol. 32, no. 11–12, pp. 1182–1200, Aug. 2021, doi: 10.1080/14783363.2019.1685864.
[25] A. Niñerola, M.-V. Sánchez-Rebull, and A.-B. Hernández-Lara, "Six Sigma literature: a bibliometric analysis," *Total Qual. Manag. Bus. Excell.*, vol. 32, no. 9–10, pp. 959–980, Jul. 2021, doi: 10.1080/14783363.2019.1652091.
[26] A. C. Scheller, T. T. Sousa-Zomer, and P. A. Cauchick-Miguel, "Lean Six Sigma in developing countries: evidence from a large Brazilian manufacturing firm," *Int. J. Lean Six Sigma*, vol. 12, no. 1, pp. 3–22, Jan. 2021, doi: 10.1108/IJLSS-09-2016-0047.
[27] M. Sony, "Design of cyber physical system architecture for industry 4.0 through lean six sigma: conceptual foundations and research issues," *Prod. Manuf. Res.*, vol. 8, no. 1, pp. 158–181, 2020, doi: 10.1080/21693277.2020.1774814.
[28] A. Kortabarria, U. Apaolaza, A. Lizarralde, and I. Amorrortu, "Analysis of an inventory system with emergency ordering Material Management without Forecasting: From MRP to Demand Driven MRP option at the time of supply disruption," *J. Ind. Eng. Manag.*, vol. 11, no. 4, pp. 632–650, 2018.
[29] A. Priyono and F. Idris, "Analysing the adoption of lean production in remanufacturing industry," *J. Ind. Eng. Manag.*, vol. 11, no. 4, pp. 697–714, 2018, doi: 10.3926/jiem.2614.
[30] H. Kropsu-Vehkapera and V. Isoherranen, "Lean approach in knowledge work," *J. Ind. Eng. Manag.*, vol. 11, no. 3, pp. 429–444, 2018, doi: 10.3926/jiem.2595.
[31] M. Uluskan and M. G. Karşı, "Predictive Six Sigma for Turkish manufacturers: utilization of machine learning tools in DMAIC," *Int. J. Lean Six Sigma*, vol. 14, no. 3, pp. 630–652, Jan. 2023, doi: 10.1108/IJLSS-02-2022-0046.
[32] M. Smętkowska and B. Mrugalska, "Using Six Sigma DMAIC to Improve the Quality of the Production Process: A Case Study," *Procedia - Soc. Behav. Sci.*, vol. 238, pp. 590–596, 2018, doi: 10.1016/j.sbspro.2018.04.039.
[33] N. Li, C. Laux, and J. Antony, "Designing for Six Sigma in a private organization in China under TQM implementation: A case study," *Qual. Eng.*, vol. 30, no. 3, pp. 405–418, Jul. 2018, doi: 10.1080/08982112.2018.1475674.
[34] F. Almaz and N. Akar, "The academic pattern of the Lean Six Sigma approach: a descriptive content analysis of project-based studies within Turkey," *Int. J. Lean Six Sigma*, vol. 14, no. 3, pp. 588–609, Jan. 2023, doi: 10.1108/IJLSS-02-2022-0031.
[35] A. Laureani and J. Antony, "Leadership – a critical success factor for the effective implementation of Lean Six Sigma," *Total Qual. Manag. Bus. Excell.*, vol. 29, no. 5–6, pp. 502–523, Apr. 2018, doi: 10.1080/14783363.2016.1211480.
[36] J. Hill, A. J. Thomas, R. K. Mason-Jones, and S. El-Kateb, "The implementation of a Lean Six Sigma framework to enhance operational performance in an MRO facility," *Prod. Manuf. Res.*, vol. 6, no. 1, pp. 26–48, 2018, doi: 10.1080/21693277.2017.1417179.