Volume 3, No. 5 May 2024 (574-585)
p-ISSN 2980-4868 | e-ISSN 2980-4841
https://ajesh.ph/index.php/gp

Using the Lean and Green Six Sigma Method at PT. XYZ, this Painting Process aims to Reduce Tosou Butsu Alloy Wheel Defects

Iwan Oktavianto[1*], Ellysa Nursanti[2], Fuad Achmadi[3]
[1,2,3]Malang National Institute of Technology, Malang, East Java, Indonesia
E-mail: khafi.raihan14@gmail.com

ABSTRACT
Aluminium wheels are a significant component of the automotive industry, but opinions about their quality are primarily based on how they look. As a result, finishing is crucial to the production process in the wheel industry. Efforts must be made to reduce the frequency of Tosou Butsu flaws in the painting process, which most frequently occur in the paint section, even though there are still a lot of errors in the wheel production process. Therefore, to lessen the chance of Tosou Butsu faults developing during the wheel finishing process, the Lean & Green Six Sigma technique is applied. Measure, Analyze, Improve, Control, and Define are the five stages of the Six Sigma methodology (DMAIC). Conversely, the Six Sigma level has grown from 3,417σ, which was the level before the Sigma was repaired, to 3,750σ in Sigma level 3 conditions, or level 4 conditions, with the potential for Tosou Butsu defects to occur at 12104 for a million production processes. Six Sigma is then applied to in this investigation, the painting procedure was able to lower the percentage of Tosou Butsu faults from 0.0276 to 0.0121. In order to optimize efficiency and focus on system mechanisms that align with standard operating procedures and human resource development, the Six Sigma process needs to be applied regularly and refined until the Sigma level reaches 6σ.
Keywords: Lean and Green Six Sigma, DMAIC, FMEA, Defect Tosou Butsu.

INTRODUCTION

Aluminium rims are the primary component produced for the car industry (Karolina & Andrzej, 2021). High-quality aluminium wheels must be produced by aluminium wheel manufacturers. The primary demand of durability must also be accompanied by an appealing appearance to draw in more customers and raise costs (Ashraf et al., 2022; Mahalik et al., 2021).

For this reason, the industrial finishing process for wheel rims is crucial to the entire manufacturing process.

Aluminium wheel manufacture is the primary automotive component industry. Aluminium wheel manufacturers must produce high-quality aluminium wheels (Zanchini et al., 2023). In addition to durability, an appealing appearance is necessary to draw in customers and raise the product's selling price. As a result, finishing is crucial to the production process in the wheel industry (Luo et al., 2022).

A product's overall quality, or its ability to surpass the expectations of its customers, is referred to as its quality (Uzir et al., 2021). A product is said to be of good quality if it achieves its intended function. This aligns with the concept of superior products (Qin et al., 2022; Wei et al., 2021). Consequently, completed goods ought to fulfil the company has established specifications. Data from April to December 2021, however, indicates that a large number of faults still occur; a total of 11 categories of defects were found. Approximately 41.43% of all product defects are butsu faults, which are errors in the process after spraying produced by dirt or dust particles that fall and attach to the surface of the wheel rim. Mist spray has a big impact on how clean work facilities—like spray booths, internal offices, ovens, storage areas, and cooling areas—are. Poor processes will result in flaws, and these shortcomings in product quality can cost the company money in the form of waste paint and sanding materials as well as extra flaws like scratches from sanding too rough. Reduced production efficiency is the outcome of process improvements.

To address the challenges posed by Tosou Butsu defects, particularly noticeable in automotive wheel rim manufacturing, a comprehensive approach is essential [3]. Employing methodologies like Lean and Green Six Sigma becomes imperative. Lean focuses on waste reduction and process optimization, while Six Sigma targets defect minimization and quality enhancement. Integrating these methodologies can effectively tackle Tosou Butsu flaws, thereby reducing waste and improving product quality. This integrated approach not only enhances operational efficiency but also aligns with environmental sustainability goals, making it a holistic solution for mitigating Tosou Butsu defects in painting processes.

RESEARCH METHODS

A product's quality is determined by its ability to display attributes including durability, accuracy, dependability, friendliness, and ease of maintenance (Arifin & Prawiro, 2022; Mahsyar & Surapati, 2020). The process of control involves keeping an eye on output, comparing it to standards, identifying nonconformities, and adjusting practices as necessary to bring them into compliance with standards (Talan et al., 2021; Tat et al., 2022). A product's performance, correctness, normalcy, durability, specialization, performance, and aesthetics are only a few of the factors that can be used to assess its quality(Harianto et al., 2020; Qin et al., 2022).

Applying a polymer or other metallic coating on a metal specimen in order to change its surface properties is known as finishing. Giving the product a nice look and great aesthetic value is the goal of the finishing process (Awuku et al., 2021; Son et al., 2020). The wheel painting process is often completed by the painting department, which also handles the washing, painting, and coating steps (Brand et al., 2023; Liu et al., 2022). They employ three different kinds of paint: liquid, priming, powder, and clear coat, which serves as a layer of protection (Kumar et al., 2024; Ramacciotti et al., 2024).

Combining Lean and Six Sigma principles, Lean Six Sigma, or LSS, aims to decrease waste while raising profitability and customer satisfaction. In essence, the Measure and Analyze stages of the Lean methodology typically do not yield tangible outcomes. While Six Sigma aims to reduce variability in value-added processes, Lean Six Sigma goes a step further by identifying both non-value-added and value-added elements, ensuring that value-added components operate smoothly within the process. However, Six Sigma alone may not sustain continuous process improvement at the same pace (Tampubolon & Purba, 2021).

The population under research is Tosou Butsu problems that develop between October 2021 and January 2022. The company supplied information on problems that happened during that time for our study. The flaws that were seen prior to repair therapy during the July–September 2021 period were then compared to this data. After that, a Moving Range Chart was employed to evaluate the Six Sigma process. Finally, conclusions are drawn based on the sigma level before and after improvement.

RESULTS AND DISCUSSION

Data Processing

The first stage in determining which product or process needs to be improved is called "Define." There were found to be eleven different kinds of product faults between February and July of 2022. Yogore, Hajiki, Ito Butsu, Kuro Butsu, Yuzuhada, Tare, Utsubuki, Tare/Utsubuki, Zara, and Mist Spray are a few of them. This study uses a Pareto chart to rank the 11 categories of defects listed above and establish a repair priority list for wheel rim issues.

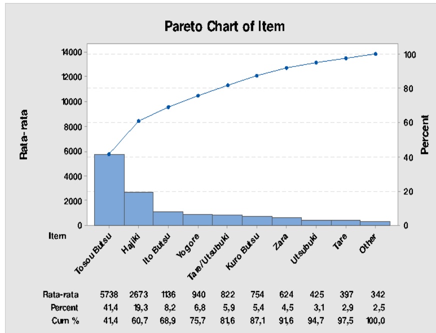

Figure 1. Pareto chart 3 CTQ

The most prevalent kind of wheel defect is the Tosou Butsu C1 defect type, which needs to be fixed, as the following Pareto diagram illustrates. Second place goes to the Ito Butsu C2 defect type, then the Kuro Butsu C3 defect type.

Table 1. Critical to quality from February to July 2022

Month	Total Production (Unit)	Total Defect Butsu	Types Of Butsu			Total Wasted Product(Unit)
			C1	C2	C3	
February	291689	9155	7348	1207	600	15498
March	295550	10609	8234	1606	769	19721
April	275259	7886	6087	891	908	14436
May	225687	5972	4500	799	673	11707
June	270066	6172	4241	1138	793	11231
July	297496	5971	4018	1172	781	10505
Total	1655747	45765	34428	6813	4524	83098

This indicates a considerable loss in terms of financing or expenditures, with a total percentage of 55.07% of all faults in the painting process arising from Butsu flaws (Tosou, Ito, and Kuro Butsu). There will be 2.28 tons of trash and lost material produced each month, which could have a greenhouse effect. The total cost of all painting faults came to IDR 260,976,356 on average; labor costs came to IDR 18,200,000, and lost material costs came to IDR 242,776,356.

The following stage involves using secondary data on the quantity of goods and faulty goods from the production data centre to assess different process calculations and product quality. Once the DPMO value and sigma level are established, the process capability level (CP) must be ascertained as the final step in the Measure phase. The results of the process capability estimations are shown in Table 2.

Tabel 2. Results of the process capability calculation (CP)

Step	Action	Equality	The Calculation Results

1.	Which procedure are you curious about?	-	Production Process for Alloy Wheel Products
2.	What number of transaction units were completed?	-	1655747
3.	How many unsuccessful transaction units were there?	-	45765
4.	Defect (error) rate calculation based on step 3	= Step 3 / Step 2	0.027640092
5.	Ascertain the quantity of possible CTQs that might lead to a Butsu fault.	CTQ	3 (bab 4.1.2)
6.	Determine the likelihood of a defect (error) rate for each CTQ feature.	= Step 4 / Step 5	0.0928879 (9.2888%)
7.	Determine the defect probability per million opportunities (DPMO).	= Step 6 x 1.000.000	27640.092357
8.	Step 7: Convert DPMO to sigma value (refer to table 4.13).	-	3.417σ
9.	Make inferences	-	The capabilities of Sigma are 3,417

The measuring procedure (Measure) is followed by the analytical process (Analyze). The Failure Mode and Effect Analysis (FMEA) method and Pareto diagram analysis are the two techniques utilized in the study of wheel product defects. With the use of the treatment groups shown in the Fishbone diagram below, any potential fix for the issue may be found and grouped.

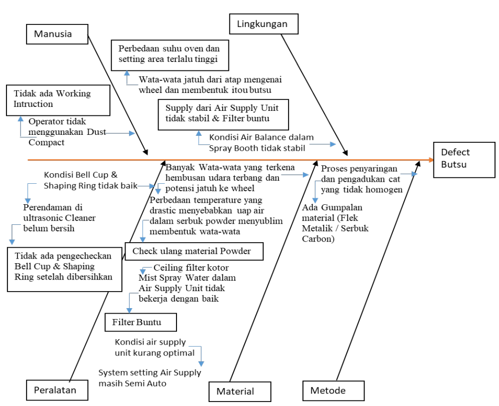

Figure 2. Fishbone Diagram

The Fishbone diagram shows where improvements can be made, and it is expected that by making the necessary adjustments, the percentage of wheel surface faults will go down. The following table shows that, in the three months from October to December 2022, following the implementation of this upgrade, there was a considerable decrease in the number of Tosou Butsu Defects:

Table 3. After repair, the product data is flawed

No	Month	Total Production(Unit)	Type Of Defect			Total Production Defect (Unit)	(%)
			C1	C2	C3		Defect
1	Oct	285327	2083	1030	615	3728	1.31%
2	Nov	273696	2037	857	534	3428	1.25%
3	Dec	266738	1824	664	351	2839	1.06%
Total		825761	5944	2551	1500	9995	1.21%
Average		275253	1981	850	500	3332	1.21%

In all, Butsu Defects (Tosou, Ito, and Kuro) constituted 55.07% of all Painting Process Defects. These defects result in material loss and lower the monthly average of greenhouse effect waste to just 0.91 tons. The average monthly cost for all painting process flaws is also decreased to IDR 114,033,278 with additional expenses of IDR 7,985,714 for labor and IDR 106,047,564 for missing materials. By putting these improvement initiatives into practice, PT XYZ can reduce losses and boost production effectiveness.

The production data from the aforesaid implementation (CP) is then used to remeasure the control chart (P), DPMO, sigma level, and process capability. This aims to find out how much the quality of the wheel rim production process can be improved by implementing changes for three months. Table 4 documents the quality gains made possible by the quality control chart (P) instrument.

Table 4. Control chart (P) following repair

No	Production time	Total Defect Product	Center Line	UCLp	LCLp	Defect Proportion
1	Oct	3728	0,0121	0.0800	-0.0131	0.0131
2	Nov	3428	0,0121	0.0785	-0.0125	0.0125
3	Dec	2839	0,0121	0.0732	-0.0106	0.0106

Total	9995	0,0121	0.0774	-0.0121	0.0121
Average	3332	0,0121	0,0774	-0,0121	0,0121

Table 4. shows that, compared to before the repair (0.0276), the average percentage of flaws is lower (0.0121) following the application of the repair solution. This demonstrates that the proportion of damaged goods decreases following repairs.

To assess the quality improvement process, it's also critical to comprehend how the DPMO value and sigma level after improvement are calculated. The computation of the DPMO value and sigma level following improvement is displayed in Table 5.

Table 5. Sigma level and DPMO value upon repair

No	Production Time	Total Production	Total Defect Product	DPMO	Level sigma (σ)
1	Oct	285327	3728	13066	3.72σ
2	Nov	273696	3428	12525	3.74σ
3	Dec	266738	2839	10643	3.80σ
Total		825761	9995	12104	3.75σ
Rata-rata		275254	3332	12104	3.75σ

Following four months of putting the suggested adjustments into practice, the data above demonstrates an improvement in the quality of the production process. This is further supported by the fact that the average DPMO value after repair is lower (12104) than it was before repair (27640), and that the Sigma Level is greater (3.75σ) after repair than it was before repair (3.42σ).

CONCLUSION

Between February and July 2022, the production process yielded an average error proportion of 0.0276, with a sigma value of 3.417σ and a DPMO value of 27640. This stands in contrast to the performance of the production process during the October-December 2022 period, after recommended improvements were implemented. During this period, the DPMO value was 12104, the average defect proportion was 0.0121, and the sigma value was 3.75σ. These findings indicate that the company is currently operating at a level of 3.75 σ, which is the ideal sigma value. This contributes to reducing the PT's average monthly losses. Prior to repair efforts, the industrial waste contribution due to lost material was 2.28 tons, which decreased to

0.91 tons following the repairs, resulting in a reduction of waste by 1.37 tons. Additionally, based on the results of Failure Modes and Effects Analysis (FMEA), the causes of process failures resulting in defects in rim packaging are identified. Tosou Butsu is mainly caused by the poor condition of the Bell Cup and shaping ring, unstable air balance, and the ongoing lack of homogeneity in the paint material, which also contributes to spray process instability. Ito Butsu faults are induced by the presence of Wata-Wata, caused by the sharp temperature difference after the powder oven and powder setting region. Kuro Butsu issues primarily stem from an unclean spray environment, attributed to the poor condition of the Air Supply Unit and intermittent filter replacement.

BIBLIOGRAPHY

Arifin, I., & Prawiro, A. M. B. (2022). Prinsip-Prinsip dalam Pemasaran Syariah. *Misykat Al-Anwar Jurnal Kajian Islam Dan Masyarakat*, *5*(2), 261–274.

Ashraf, M., Iqbal, M. F., Rauf, M., Ashraf, M. U., Ulhaq, A., Muhammad, H., & Liu, Q. (2022). Developing a sustainable concrete incorporating bentonite clay and silica fume: Mechanical and durability performance. *Journal of Cleaner Production*, *337*, 130315.

Awuku, S. A., Bennadji, A., Muhammad-Sukki, F., & Sellami, N. (2021). Myth or gold? The power of aesthetics in the adoption of building integrated photovoltaics (BIPVs). *Energy Nexus*, *4*, 100021.

Brand, J., Wain, A., Rode, A. V, Madden, S., King, P. L., & Rapp, L. (2023). Comparison between nanosecond and femtosecond laser pulses for the removal of spray paint from granite surfaces. *Journal of Cultural Heritage*, *62*, 329–338.

Harianto, D., Hutabarat, J., & Achmadi, F. (2020). Strategi Perbaikan Kecacatan Produk Menggunakan FMEA dan AHP Untuk Produksi Cut Rag Tobacco. *JURNAL TEKNOLOGI DAN MANAJEMEN INDUSTRI*, *6*(1), 27–32. https://doi.org/10.36040/jtmi.v6i1.2627

Karolina, C., & Andrzej, P. (n.d.). Improving the manufacturing process of aluminium RIMS. *System Safety: Human-Technical Facility-Environment*, *3*(1), 38–46.

Kumar, S., Kumar, S., & Namburi, E. P. (2024). Functional Paints and Coatings. In *Novel Defence Functional and Engineering Materials (NDFEM) Volume 1: Functional Materials for Defence Applications* (pp. 219–246). Springer.

Liu, X., Le Bourvellec, C., Yu, J., Zhao, L., Wang, K., Tao, Y., Renard, C. M. G. C., & Hu, Z. (2022). Trends and challenges on fruit and vegetable processing: Insights into sustainable, traceable, precise, healthy, intelligent, personalized and local innovative food products. *Trends in Food Science & Technology*, *125*, 12–25.

Luo, A. A., Sachdev, A. K., & Apelian, D. (2022). Alloy development and process innovations for light metals casting. *Journal of Materials Processing Technology*, *306*, 117606.

Mahalik, M. K., Mallick, H., & Padhan, H. (2021). Do educational levels influence the environmental quality? The role of renewable and non-renewable energy demand in selected BRICS countries with a new policy perspective. *Renewable Energy*, *164*, 419–432.

Mahsyar, S., & Surapati, U. (2020). Effect of service quality and product quality on customer satisfaction and loyalty. *International Journal of Economics, Business and Accounting Research (IJEBAR)*, *4*(01).

Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research*, *7*, 100265.

Ramacciotti, F., Sciutto, G., Cazals, L., Biagini, D., Reale, S., Degano, I., Focarete, M. L., Mazzeo, R., Thoury, M., & Bertrand, L. (2024). Microporous electrospun nonwovens combined with green solvents for the selective peel-off of thin coatings from painting surfaces. *Journal of Colloid and Interface Science*.

Son, S., Liu, Y., Chae, D., & Lee, H. (2020). Cross-linked porous polymeric coating without a metal-reflective layer for sub-ambient radiative cooling. *ACS Applied Materials & Interfaces*, *12*(52), 57832–57839.

Talan, A., Tyagi, R. D., & Drogui, P. (2021). Critical review on insight into the impacts of different inhibitors and performance inhibition of anammox process with control strategies. *Environmental Technology & Innovation*, *23*, 101553.

Tampubolon, S., & Purba, H. H. (2021). Lean six sigma implementation, a systematic literature review. *International Journal of Production Management and Engineering*, *9*(2), 125–139.

Tat, F., Herwanty, E., Selasa, P., Mochsen, R., Romana, A. B. Y. H., & Banase, E. F. T. (2022). Penerapan Point Of Care Quality Improvement (POCQI) terhadap Dokumentasi Keperawatan dI RSUD Kabupaten. *Window of Health: Jurnal Kesehatan*, 556–567.

Uzir, M. U. H., Al Halbusi, H., Thurasamy, R., Hock, R. L. T., Aljaberi, M. A., Hasan, N., & Hamid, M. (2021). The effects of service quality, perceived value and trust in home delivery service personnel on customer satisfaction: Evidence from a developing country. *Journal of Retailing and Consumer Services*, *63*, 102721.

Wei, J., Li, Z., Lyapustin, A., Sun, L., Peng, Y., Xue, W., Su, T., & Cribb, M. (2021). Reconstructing 1-km-resolution high-quality PM2. 5 data records from 2000 to 2018 in China: spatiotemporal variations and policy implications. *Remote Sensing of Environment*, *252*, 112136.

Zanchini, M., Longhi, D., Mantovani, S., Puglisi, F., & Giacalone, M. (2023). Fatigue and failure analysis of aluminium and composite automotive wheel rims: Experimental and numerical investigation. *Engineering Failure Analysis*, *146*, 107064.