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Quality Control in the Automotive Component Electroplating Process Service Industry with the DMAIC and FMEA Approaches

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Abstrak

Penelitian ini bertujuan untuk mengidentifikasi penyebab utama cacat produk pada proses elektroplating di PT. X, sebuah perusahaan manufaktur komponen otomotif, serta merumuskan usulan perbaikan guna meningkatkan kualitas produk. Pendekatan yang digunakan adalah Six Sigma-DMAIC (Define, Measure, Analyze, Improve, Control) yang dikombinasikan dengan metode Failure Mode and Effect Analysis (FMEA). Tahap awal penelitian dilakukan dengan mengidentifikasi jenis cacat Produk. Hasil pengukuran menunjukkan nilai Defects Per Million Opportunities (DPMO) sebesar 18909 dengan nilai sigma 3,59, yang mengindikasikan kualitas masih berada pada level rata-rata industri dan perlu perbaikan. Analisis Pareto mengungkapkan bahwa cacat dominan adalah dirty dengan kontribusi 37,7%. Melalui analisis sebab akibat dan FMEA, faktor penyebab utama cacat dirty karena operator tidak memasang plate dummy, proses rinsing yang kurang optimal, lingkungan berdebu, serta kontaminasi material dan mesin. Nilai Risk Priority Number (RPN) tertinggi sebesar 560 menegaskan bahwa faktor manusia menjadi penyebab utama cacat. Usulan perbaikan meliputi pemasangan plate dummy, penambahan proses rinsing, pembersihan mesin transporter, penutupan area produksi, serta penggunaan sarung tangan dan pakaian kerja yang bersih. Implementasi perbaikan terbukti efektif dengan menurunkan DPMO menjadi 9583, meningkatkan nilai sigma menjadi 3,84, dan menurunkan dirty defect dari 12% menjadi 2,25%. Hasil penelitian membuktikan bahwa kombinasi DMAIC dan FMEA mampu meningkatkan kualitas produk secara signifikan. Temuan ini dapat dijadikan referensi untuk penerapan perbaikan berkelanjutan di industri jasa elektroplating maupun sektor manufaktur lain yang menghadapi permasalahan serupa
***Kata Kunci**: DMAIC, FMEA, DPMO, Sigma, Electroplating*

Abstract

This research aims to identify main causes of product defects in electroplating process at PT. X, an automotive component manufacturing company, and formulate improvement proposals to enhance product quality. Approach used is Six Sigma-DMAIC (Define, Measure, Analyze, Improve, Control) combined with Failure Mode and Effect Analysis (FMEA) method. Initial research was conducted by identifying types of product defects. Measurement results showed a Defects Per Million Opportunities (DPMO) value of 18909 with a sigma value of 3,59, indicating that quality was within industry average levels and required improvement. Pareto analysis revealed that a dominant defect was dirtiness, contributing 37,7%. Through cause-and-effect analysis and FMEA, main factors causing dirtiness were operators not installing dummy plates, suboptimal rinsing processes, dusty environments, and material and machine contamination. Highest Risk Priority Number (RPN) of 560 confirmed that human factors were the main cause of defects. Proposed improvements include installing dummy plates, adding a rinsing process, cleaning the transporter machine, closing the production area, and using clean gloves and work clothes. The implementation of these improvements proved to be effective, reducing the DPMO to 9583, increasing sigma to 3,84, and reducing dirty defects from 12% to 2,25%. Results of research prove how combining DMAIC and FMEA could significantly improve product quality. These findings can be used as a reference for implementing continuous improvement in electroplating services and other manufacturing sectors facing similar problems.
***Keywords**: DMAIC, FMEA, DPMO, Sigma, Electroplating*

1. Introduction

A Company's ability to compete and survive sustainably is influenced by product quality and productivity levels, which are key factors in the success of production systems in Industry (Hernandoko et al., 2024). Meanwhile various characteristics and conditions can affect the success or failure of a product in meeting customer standards and expectations (Reva et al., 2025). Attribute and variable specifications are used as a reference to determine the quality of a product. A product that does not meet specifications can be caused by errors in the production process, inadequate quality control, or raw materials that do not meet standards. Product defects are phenomena that indicate imperfections in the product. Product defects can be caused by improper manufacturing processes, improper use of machines, or poor quality raw materials and several other causal factors. Human factors are another cause of product defects due to subjective inspection methods (Retnaningsih et al., 2025). Variations in the production

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process can produce products with different qualities that can affect customer satisfaction. This variation is due to the ability to produce uniform products.

PT.X is one of the automotive component companies in the field of electroplating services for car accessories. The electroplating process is the process of coating a metal surface with another metal using an electric current. This process is used in the manufacturing industry to improve the surface properties of products, such as corrosion resistance, hardness, conductivity, or aesthetic appearance (Insani & Azizah, 2022)(Afandi et al., 2022). The electroplating process can be done manually or with more sophisticated automation technology (Fatah & Al-Faritsy, 2021). This process includes cleaning, rinsing, coating and protection after coating. The electroplating process produces output in the form of high-quality chrome bright plating for car interior and exterior accessories. In several months, the performance of the quality aspect in Company X has decreased. This decrease can be seen from the indication of the emergence of defects on the product after the electroplating process. The defect rate is quite high, averaging 10,67%, and the phenomenon of product defects exceeding the Company's standards, an average of 7,69%, has an impact on various aspects. This includes rework costs for repairable products, wasteful scrap due to product disposal, and increased customer claim handling costs. Furthermore, the high level of product defects impacts productivity, as resources are used to repair defective products. Another impact is that the Company is unable to meet delivery requirements, which can lead to customer dissatisfaction (Razak, 2019). For this reason, more in-depth research is needed to find the cause of product defects and what improvements need to be made so that product defects do not appear repeatedly.

Quality control is a key element in the manufacturing and service industries, including in the electroplating process. To ensure that the products or services produced are of high quality, it is necessary to establish standards in terms of both dimensions and visuals. Quality control is one of the techniques to increase the effectiveness of the Company to prevent the occurrence of non-conforming products, so that it can reduce waste in terms of raw materials, and human resources so that productivity increases (Suryatman et al., 2020). In quality control, monitoring the changing process conditions can be done through process capability analysis (Putri & Rimantho, 2022). Enhancing processes to improve product quality can be achieved through analysis using DMAIC Approach (Wang et al., 2025). Implementation of DMAIC and Six Sigma has proven effective in reducing defects and significantly improving production process efficiency and product quality (Mittal et al., 2023) (Riyanto et al., 2024)(Rinawati & Sriyanto, 2024)

Failure Modes and Effects Analysis (FMEA) is an analysis method used to identify, evaluate, and reduce the risk of failure/defects of a product (Basori, 2019). Therefore, continuous improvement is needed through improvement efforts with the FMEA method (Kholil, 2013). The FMEA approach can be used to find the main sources of causes of product failure (Sutiono & Widiyaningrum, Dzakiyah, 2023)(Wicaksono et al., 2023). The main cause source is based on the highest RPN value which then becomes a priority for immediate improvement (Supoyo & Darajatun, 2023). Several quality control studies using FMEA have been widely applied and are able to reduce the level of product defects. Implementation of the FMEA method systematically can help companies minimize risks of production process failure by establishing corrective measures in order of priority based on RPN analysis results (Prasetya et al., 2021)

DMAIC is an approach to analyzing product failure in a structured manner (Define, Measure, Analyze, Improve, Control) (Muchammad et al., 2023)(Pradana & Supriyati, 2023). DMAIC is effective in identifying root causes of quality issues, analyzing risks through FMEA, and providing solutions based on continuous improvement (Asnan, 2019). One of DMAIC's phases is Measure, which is used to determine sigma level values within the company. Research in the railway component industry with the aim of reducing costs and improving quality showed an increase in the sigma value of 72.5% (Sumasto et al., 2022). Quality control by finding the sigma value has also been carried out in the agribusiness industry and it is known that the sigma value is 3.7 so that improvements still need to be made to achieve a sigma value of 6 (Anisa Rosyidasari & Iftadi, 2020). Product failure analysis with the DMAIC approach can also be started when machine performance/OEE value is low (Supriyati, Widyatri, 2024) (Supriyati & Wahyu Hadikristanto, 2024). A research gap is evident in the limited number of studies that comprehensively combine FMEA, fishbone diagrams, and DMAIC methods in the electroplating industry. Previous research has focused on only one method, thus failing to demonstrate how the synergy of these three methods can improve product quality, increase sigma, and enhance process efficiency.

2. Research Methods

This research began with determining objects and subjects to facilitate identification of problems existing in companies. Reviewing relevant literature and research theories. Types and collection of data needed in this research are primary and secondary data. Primary data in this research are results of observation to research locations by conducting direct observation of objects to be researched, as well as examining data and facts in the field on how the production process takes place and how quality control is carried out at the company. Primary data also include interviews to obtain process flow data and documentation of the production process. Meanwhile, secondary data was obtained from data

already available at the company in form of data on number of defect products and types of defects. Research framework is illustrated in Figure 1

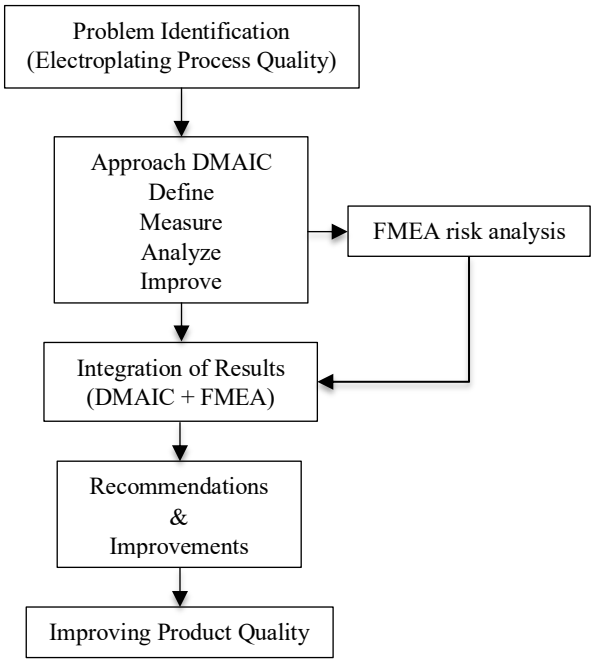


Figure 1: Research Framework

In this research the method used as an analysis tool is DMAIC (Define, Measure, Analyze, Improvement, Control). Define is the stage of defining the type of potential defect and determining quality characteristics (CTQ) in the form of key characters that make a product not meet customer expectations (Heryad, 2018). Measure is the stage of collecting and measuring data to be analyzed (Siregar, 2019). This phase is carried out by measuring the DPMO and sigma values. Six Sigma's DMAIC approach is used to identify root causes of defects and determine appropriate corrective actions (Helmi et al., 2024).

Analyze is a phase to determine deeper analysis which is a priority for further research. This phase is represented in a bar chart. Subsequently, analyze the highest type of defect in products by displaying it in a Pareto chart, find root causes of the highest defects with 4M and 1E through FGD (Focus Group Discussion) and FMEA (Failure Mode and Effect Analysis) analysis. Improvement involves setting priorities for improvement action plans based on RPN values to enhance quality. Control involves designing quality improvement results, which are then integrated into the company's business practices as quality control measures. Control by designing quality improvement results which are then integrated into the company's business practices as a quality control step. Effective quality control is an important factor in maintaining a company's reputation and ensuring customer satisfaction (Khoiri et al., 2024).

3. Results and Discussion

PT. X carries out the electroplating process of car accessories for several vehicle brands. The electroplating process consists of the jigging process (installing materials on the jig), the plating process (coating materials with metal), the unjigging process (removing products from the jig), and the inspection process (checking the quality of the coating results). PT. X produces component products in the form of chrome bright plating products that can be used directly on vehicles.

3.1 Define

In the electroplating process, this stage determines and defines the types of non-conformities/defects in the product after the coating process. Based on the results of observations and interviews, it is known that there are six types of potential defects in electroplating products. These types of defects affect the quality of the product, thus becoming CTQ (Critical to Quality). Table 1 is the type and definition of each type of defect

Table 1: Types and Definitions of Defects

No	Types of Defects	Definition
1	*Dirty*	Product defects in the form of dirt attached to the product
2	*Scratch unjigging*	Defects due to scratches on the product after the process
3	*Bending*	Defects due to unevenness on the product surface
4	*Copper*	Defects due to the color that appears like copper
5	*Scratch jigging*	Defects due to scratches on the product during the loading process
6	*No plating*	Defect due to the absence of a metal layer on the product

3.2 Measure

Measuring the DPMO value by collecting data on the amount of production, the number of defects and CTQ. The DPMO variable is influenced by the amount of production, the number of defects and the chance of defects or CTQ. Finding the DPMO value can be seen in the following equation.

$$DPMO = \frac{Number\ of\ Defective\ Products}{Number\ of\ ProductionxCTQ} \text{x} 1000000$$

(Hamashiah, 2023)

Meanwhile, the sigma value can be converted from the sigma table or can be calculated using the equation

$$Sigma\ Level = Normsinv\ \frac{1000000-DPMO}{1000000} + 1.5$$

(Hia, 2024)

The measurement results for the DPMO value obtained an average of 18909 so that if converted to a sigma value of 3,59. This value shows that the Company has reached the average value of the industry in Indonesia (Suherman & Cahyana, 2019). A more in-depth analysis is needed, because in several months the company could not meet consumer demand because the defect rate exceeded the standard. In addition, it is also to increase the sigma value so that the Company is able to compete and maintain the quality of the products produced.

3.3 Analyze

Production data and the number of defects show that the product defect rate is still high, but this research focuses on products with the highest % of defects as shown in the following table.

Table 2: Quantity and % Defects

No	Part Name	Production Qty	Qty Defective Products	% Product Defects
1	*H-Mark 110 emblem*	21000	6532	31,1%
2	*Handle D17 D Chrome RH*	15000	562	3,7%
3	*Handle D55 RH*	12000	306	2,6%
4	*Handle D55 LH*	12000	259	2,2%
5	H-Mark 115 emblem	15000	1600	10,7%
6	Handle D17 D Chrome LH	15000	1345	9,0%

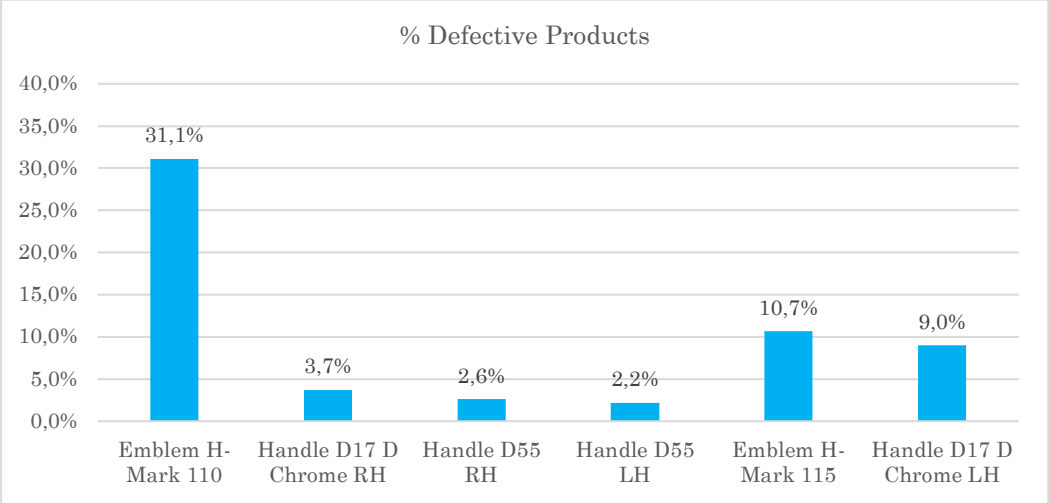


Figure 2. Percentage of defective products

The Emblem H-Mark 110 product is the product with the highest percentage of defects, so it will be analyzed further. The average level and type of defects for eight months for the Emblem H-Mark 110 product can be seen in the following table and Pareto chart

Table 3: Type & Percentage of Defects

Types of Defects	Number of Defects	% Defects	% Accumulation
Dirty	2460	37,7%	37,7%
Scratch Unjigging	1600	24,5%	62,2%
Copper	1345	20,6%	82,7%
Bending	562	8,6%	91,4%
Scratch Jigging	306	4,7%	96,0%
No Plating	259	4,0%	100,0%
Total	6532		

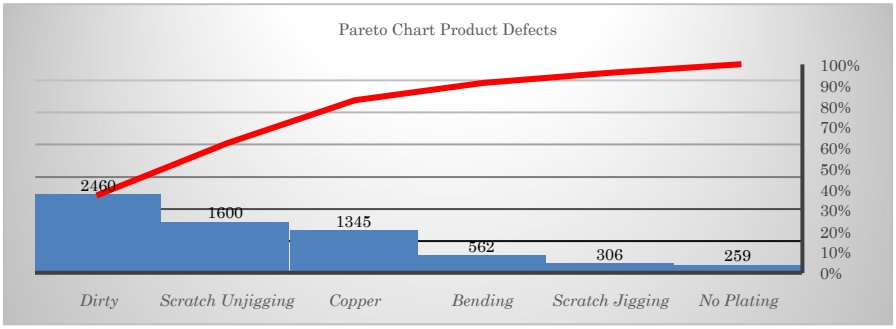


Figure 3. Pareto Diagram of Types and % of Defects

The results of Pareto analysis show that the research focuses on dirty defects with a quantity of 2460 and a defect rate of 37.7%. To reduce/eliminate these defects, it is necessary to find the root cause of dirty defects. Therefore, as a further step, a Focus Group Discussion (FGD) was held with the relevant departments and visualized through a cause-and-effect diagram, which revealed several causes of dirty defects.

Table 4: 4M & 1E Analysis of Dirty Defects

Analysis	Cause of Defects	Consequences of Defects
Man	Operator No installplate dummy	Dirt stick on the product
	The operator at the time of releasing the product does not use sarong hand Which clean	Dirt stick on the product
Method	only one way of processrinse	Product results are lackingmaximum
Machine	Rust particles from the engine transporter fall to solution	Metal particle contamination on solution
Material	Foreign objects attached to the Material	Contamination particle metal on product
Environment	Dust flying and enter into the book	Product dirty

FMEA analysis is performed using FMEA spreadsheet. Each cause of the problem is searched for the RPN value and then arranged from the largest to the smallest value. The cause with the largest RPN value is the main cause of product defects. Filling in the FMEA spreadsheet is done by brainstorming with the company's Quality Control department . The brainstorming is done to find out the effects caused by each cause, determine the severity, occurrence and detection values of each cause of the problem. The severity, occurrence and detection values are between 1-10, the value is given based on considerations and references in the references. For more details, Table 5 shows the spreadsheet of brainstorming results with related parties in the Compan

Table 5: FMEA of Dirty Product Defects

Product Target	Analysis	Causes of Defects	Defect Effects	Severity	Occurrence	Detection	RPN	Rank
Production according to the set target	*Man*	The operator does not install a dummy plate	Dirt sticks to the product	7	8	10	560	1
		The operator did not wear clean gloves when removing the product.		4	7	4	112	6
	Method	There is only one way of rinsing process	Product results are not optimal	6	7	7	294	2
	Machine	Rust particles from the transporter engine fall into the solution	Metal particle contamination in solution	5	9	4	160	4
	Material	Foreign objects attached to the Material	Particle contamination	6	7	3	126	5
	Environment	Dust flies up and gets into the box	Gross product	5	7	8	260	3

The table above shows that causes with highest RPN value of 560 are related to operators not installing dummy plates. Severity value of 7, occurrence of 8, and detection of 10 are main causes affecting the occurrence of dirty defects, which means these causes cannot be overcome. Highest RPN value is caused by man (employees).

3.4 Improvement

Once the analysis has been completed and factors causing product defects have been identified, further Actions are to develop proposals/recommendations for improvement to reduce defects. Based on the results of the Focus Group Discussion, improvement proposals are made based on priority level using the FMEA approach. Highest RPN value becomes the priority for improvement, followed by the second highest and further down the list.

Table 6: Proposal Action For Dirty Defect

Rank	Causes of Defects	Impact	Improvement
1	The operator did not install the Dummy Plate	Dirt sticks to the product	Installing Dummy Plate during production process
2	Rinsing process is not optimal	Not clean, there is still dirt left	Adding rinsing process
3	Dusty area resulting in contamination	Gross product	Close the room & employees wear antistatic clothing
4	Rust particles from Transporter engine	Solution contaminated with metal particles	Clean the transporter machine and make a base on the bottom of the machine
5	Foreign objects attached to the material	Product contaminated with metal particles	Product inspection is carried out before the Jigging process
6	Operators wear dirty gloves during the unloading process	Dirt sticks to the product	The operator changes into new gloves

3.5 Control

Control is final stage of DMAIC cycle to monitor and control impact of implementing Improvement actions. This stage focuses on spreading and documenting actions or efforts taken (Knop, 2022)

Table 7: Dirty Defect Improvement Results (H-Mark 110 Emblem)

Types of Defects	Number of Defects (Pcs)	% Defects
Dirty	18	2,25%
Scratch Unjigging	8	1,00%
Copper	4	0,50%
Bending	7	0,87%
Scratch Jigging	0	0,00%
No Plating	9	1,12%

Results of improvement show a decrease in DMPO value to 9583 and an increase in Sigma value to 3,84. Decrease in DPMO and increase in sigma value are not significant but have a significant impact on the decrease in dirty defects from 12% to 2,25%. Previous research have focused on only one method, and although results show improvement in quality, but have not described the synergy between methods. This research is different because it combines DMAIC and FMEA in electroplating service industries. Research results prove that a combination of these two methods is more effective because it can reduce DPMO from 18909 to 9583, increase sigma value from 3,59 to 3,84, and reduce dirty defects from 12% to 2,25%. Research was only conducted at one company (PT. X), thus generalization to other industries is still limited. Improvements made are still on a short-term operational scale and have not been evaluated for their long-term impact on process stability. Economic factors have not been considered in detail (cost of improvements vs. financial benefits)

4. Conclusion

The results of analysis using Six Sigma–DMAIC and FMEA methods in electroplating processes at PT. X show that dominant defects are dirty defects, accounting for 37,7% of total defects. Main causes of dirty defects include operators not installing dummy plates, insufficient rinsing, and dusty environmental conditions. Improvement efforts included installing dummy plates, adding a rinsing process, cleaning transporter machines, using clean gloves, checking materials before jigging, and covering the production area with plastic. Implementation of these improvements successfully reduced the percentage of dirty defects from 12% to 2,25% and increased the sigma value from 3,59 to 3,84. These results prove that the application of DMAIC and FMEA can reduce defect rates, improve quality, and have a positive impact on production process efficiency. Further research can integrate the DMAIC and FMEA methods with other approaches for more comprehensive results. Expansion of research objects to various products and different production lines is needed to obtain a comparison of effectiveness

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