ENGINE HOOD DEFECT ANALYSIS OF MAUNG 4X4: MULTI-LINE OPTIMIZATION STRATEGY AND ITS IMPACT ON PRODUCTION COST AND SCHEDULE – A CASE STUDY AT PT XYZ

Putri Rizqi Oktaviena*, Purnawan Adi Wicaksono

Department of Industrial Engineering, Faculty of Engineering, Diponegoro University
Jl. Prof. Soedharto, SH, Undip Tembalang Campus, Semarang, Indonesia 50275

Abstract

This study investigates a case of mass defects in specialized vehicle engine hoods, providing a framework for production optimization while maintaining tight delivery schedules. We analyzed 81 engine hood units with dimensional gaps and surface waviness through time-cost comparisons between normal production and repair scenarios. A multi-line optimization model was developed and root causes were identified using fishbone analysis. A five-line production strategy with two shifts reduced repair time by 89,6% with only a 2.4% cost increase compared to a single-line approach. Defect repairs increased manufacturing costs by 68.1% per unit. Inadequate welding jigs were identified as the primary cause of component deformation. The multi-line optimization strategy effectively balanced quality requirements with schedule constraints, offering manufacturing industries a practical approach to manage mass defects while minimizing delivery delays.

Keywords: *defect correction; engine hood; specialized vehicle; multi-line strategy; production efficiency*

1. Introduction

Customer satisfaction is vital in manufacturing, requiring companies to meet expectations for product quality and timely delivery (Sofjan, 2011). The Master Production Schedule coordinates production processes, where delays can significantly impact customer satisfaction and potentially damage company reputation (Cheng & Podolsky, 1996).

PT XYZ, a company operating in the defense manufacturing industry, faced a challenge when all 81 front engine hoods failed quality inspection due to gaps and uneven surfaces. This required extensive rework that threatened the February 23, 2024 deadline and risked compromising the company's delivery commitments (Sulistiono, 2021).

This study aims to: (1) analyze the cost increases resulting from defects, (2) assess additional time requirements for repairs, (3) develop an efficient repair strategy, (4) determine optimal repair time requirements, and (5) identify root causes using fishbone analysis across the five M categories (Alijoyo, 2020). The research introduces a multi-line optimization model to address large-scale defects in Make-to-Order production, providing practical guidance for manufacturing industries managing quality control challenges under tight deadlines while maintaining cost efficiency.

2. Methodology

This study began with direct observations and interviews at PT XYZ to understand production processes and identify challenges. We conducted a literature review and field study to understand production processes and identify challenges. Primary data were collected by documenting the fabrication process for the front engine hood, including processing times, technical drawings, equipment lists, and defect data. Interviews with production leaders provided insights into production constraints.

Assumptions for this study include the availability of accurate data for the fabrication processes and the consistency of production methods throughout the observed periods. After data collection, time analysis, production cost estimation, and defect cause analysis were performed. The results informed strategies for improving production efficiency.

3. Results and Discussion

3.1 Product Description and Production Process

The front engine hood of the specialized vehicle is a vital component that protects the engine and contributes to the vehicle's aerodynamics. Made from 24

*Corresponding Author.
E-mail: putrioktaviena@gmail.com

precision parts of ST 37 steel plates (1.5–2 mm thick), it is chosen for its strength and formability.

The Engineering Department initiated production with technical drawings, followed by material and resource planning in the Production Planning and Warehouse Department. The Fabrication Department handles cutting, edge trimming (afbramen), bending, welding, and assembly. After painting and quality checks, the product is installed onto the Body Tubular in the Assembly Department. The full fabrication flow is shown in Figure 3.1.

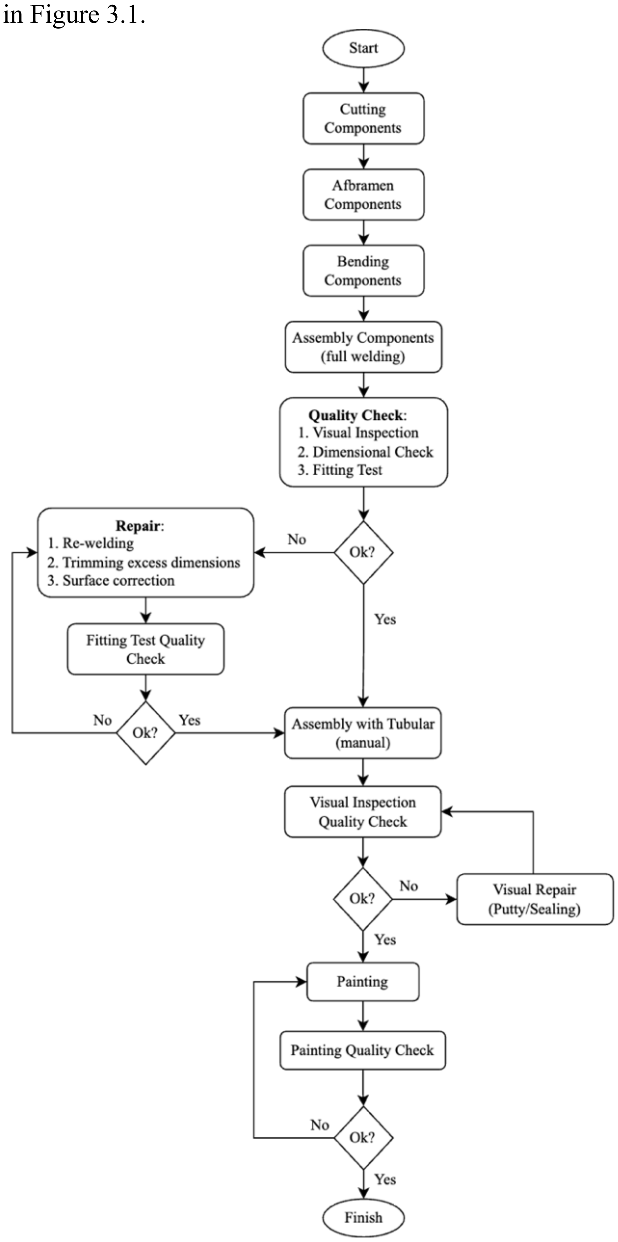

Figure 3.1 *Flowchart* of the Fabrication Sequence

3.2 Master Production Schedule & Production Status

The Master Production Schedule (MPS) was prepared by the Planning and Warehouse Department by taking into account machine capacity, material availability, labor quantity, and the lead time agreed upon with the customer.

The production of the front engine hood began on October 25, 2023, with a targeted completion date of February 23, 2024. The overall production of the specialized vehicle, including the installation of the front engine hood, is scheduled to be completed by April 5, 2024. Production Status as of January 19, 2024: All 81 units of the front engine hood have completed the fabrication stage but failed the quality inspection due to defects, thereby requiring repair prior to assembly.

3.3 Production Time and Cost Analysis

3.3.1 Production Time

An analysis of production time was conducted by comparing two conditions: the normal fabrication process (without defect repair) and fabrication with defect repair.

The production time analysis reveals a significant difference between the fabrication process without defect repair and the one involving defect correction. Under normal conditions, the actual fabrication time was recorded at 1,409 minutes per unit—107 minutes faster than the initial estimate of 1,516 minutes. This efficiency was primarily achieved during the cutting, edge trimming (afbramen), and bending processes, which also contributed to a reduction in machine usage time from 653.1 to 595.5 minutes.

Conversely, when defect repairs were included, the fabrication time increased significantly to 2,439 minutes per unit—an additional 1,030 minutes compared to the normal condition. Painting emerged as the most time-consuming process, doubling from 960 to 1,920 minutes, followed by the assembly stage (joining the hood with the tubular frame), which tripled from 30 to 90 minutes. Consequently, total machine usage also rose to 1,120.5 minutes.

The painting process involved surface puttying to correct uneven finishes, while the additional assembly time was required to adjust welding points beyond the standard area in order to eliminate gaps between the hood and the tubular frame.

These findings highlight painting and assembly as critical points in the repair process, contributing the most to the added time and workload. Therefore, implementing robust quality control measures from the early stages is essential to prevent defects and maintain production efficiency. Detailed processing times are presented in Table 3.1 and Table 3.2.

Table 3.1 Normal Fabrication Time

Work Process	Operator Time (minutes)			Machine Time (minutes)		
	Estimated	Actual	Difference	Estimated	Actual	Difference
Cutting	65	24	41	31,1	12	19,1
Afbramen	21	10	11	0	5	-5
Bending	320	253	67	67	36,5	30,5
Welding	120	142	-22	75	62	13
Assembly	30	20	10	0	0	0
Painting	960	960	0	480	480	0
Total Time	**1516**	**1409**	**107**	**653,1**	**595,5**	**57,6**

Table 3.2 Fabrication Time with Defect Repair

Work Process	Operator Time (minutes)			Machine Time (minutes)		
	Estimated	Actual	Difference	Estimated	Actual	Difference
Cutting	65	24	41	31,1	12	19,1
Afbramen	21	10	11	0	5	-5
Bending	320	253	67	67	36,5	30,5
Welding	120	142	-22	75	62	13
Assembly	30	90	-60	0	45	-45
Painting	960	1920	-960	480	960	-480
Total Time	**1516**	**2439**	**-923**	**653,1**	**1120,5**	**-467,4**

3.3.2 Production Cost

Table 3.3 presents a summary of the production costs for a single unit of the specialized vehicle front engine hood, including the estimated and actual costs for the normal production process without defect repair.

Table 3.3 Normal Production Cost

Cost Type	Normal Product		
	Estimated	Actual	Difference
Material Cost	Rp710.765	Rp710.765	Rp0
Consumable Cost	Rp446.898	Rp446.898	Rp0
Labor Cost	Rp654.364	Rp600.912	Rp53.452
Machine Cost	Rp88.959	Rp48.115	Rp40.845
Total	**Rp1.900.986**	**Rp1.806.689**	**Rp94.296**

The actual production cost for one unit of a normal (non-defective) front engine hood was Rp1,806,689.

3.3.3 Estimated Repair Time and Cost

Estimated Repair Time

The repair time estimation for 81 units of defective front engine hood focuses on two key processes: assembly with the tubular frame and painting, which require additional handling.

The repair process for the assembly with the tubular frame requires an additional 60 minutes of operator time and 45 minutes of machine time per unit. For 81 units, this translates to a total of 81 operator hours and 60.75 machine hours.

Meanwhile, the surface defect correction in the painting stage requires 960 additional operator minutes and 480 machine minutes per unit, resulting in a total of 1,296 operator hours and 648 machine hours for all units. These details are presented in Table 3.4.

Table 3.4 Estimated Repair Time

Defect	Repair Process	Difference in Operation Time (minutes)	Difference in Machine Time (minutes)	Repair Time (Hours)	
				Operator	Machine
Gap	Welding	60	45	81	60,75
Uneven Surface	Body Filler	960	480	1296	648

Estimated Labor Cost with Repair

The estimated labor cost calculation was conducted for two main repair activities: tubular assembly (welding) and surface finishing (body filler/painting), while considering variations in the number of production lines. In the welding process, each line requires 2 operators and 1 supervisor, whereas the painting process (body filler) requires 1 operator and 1 supervisor per line. As the number of lines increases, the repair time per line decreases; however, the total labor cost remains unchanged due to the inverse relationship between time and the number of lines. Table 3.5 presents the detailed estimation of labor costs under different line configurations.

Tabel 3.5 Estimated Labor Cost for Repair

Number of Lines	*Welding*			Body Filler			Total Time (days)	Total Labor Cost
	Wage/hour	Repair Time (h)	Labor Cost	Wage/hour	Repair Time (h)	Labor Cost		
1	Rp51.786	81	Rp4.194.643	Rp55.952	1296	Rp72.514.286	173	Rp76.708.929
2	Rp103.572	40,5	Rp4.194.643	Rp111.904	648	Rp72.514.286	87	Rp76.708.929
3	Rp155.358	27	Rp4.194.643	Rp167.856	432	Rp72.514.286	58	Rp76.708.929
4	Rp207.144	20,25	Rp4.194.643	Rp223.808	324	Rp72.514.286	44	Rp76.708.929
5	Rp207.144	16,2	Rp4.194.643	Rp223.808	259	Rp72.514.286	35	Rp76.708.929

Although the number of production lines increases, the total labor cost for repairing 81 units remains at Rp76,708,929. This condition enables the company to accelerate the production process without incurring additional costs.

Estimated Machine Cost with Repair

The estimated machine cost calculation is only applied to the assembly process of the tubular part (welding). For the painting process (body filler), machine usage is not counted as it is classified as part of the building's overhead cost. Table 3.6 shows the breakdown of machine usage cost.

Table 3.6 Estimated Machine Cost for Repair

Machine	Machine Hours	Power (kW)	Electricity Tariff (Rp/kWh)	Machine Cost
Welding	30,375	14,2	Rp1.263,18	Rp544.841,11
Grinding	30,375	0,9	Rp1.263,18	Rp34.532,18
Total				**Rp579.373,30**

When using 5 production lines, 5 machine sets was required to run the repair process in parallel. Therefore, the total machine cost for repairing 81 units of the front engine hood under this configuration is Rp2,896,866.48 (5 × Rp579,373.30).

Estimated Consumable Cost with Repair

The total consumable cost is obtained from the difference in actual material costs between normal production and defect repairs, multiplied by the number of units. Table 3.7 presents the consumable cost calculation.

Table 3.7 Estimated Consumable Cost with Repair

Normal Cost	Defect Repair Cost	Difference	Total Cost
Rp446.898	Rp693.497	Rp246.599	**Rp19.974.499**

Summary of Estimated Repair Time and Cost

Table 3.8 presents the recap of total estimated time and cost required to repair 81 defect units.

Tabel 3.8 Estimated Repair Time and Cost

Number of Lines	Labor Cost	Machine Cost	Consumable Cost	Total Cost	Total Time (days)	
					1 Work Shift	2 Work Shifts
1	Rp76.708.929	Rp579.373,30	Rp19.974.499	Rp97.262.801	173	87
2	Rp76.708.929	Rp1.158.746,59	Rp19.974.499	Rp97.842.174	87	44
3	Rp76.708.929	Rp1.738.119,89	Rp19.974.499	Rp98.421.547	58	29
4	Rp76.708.929	Rp2.317.493,19	Rp19.974.499	Rp99.000.921	44	22
5	**Rp76.708.929**	**Rp2.896.866,48**	**Rp19.974.499**	**Rp99.580.294**	**35**	**18**

Based on the Master Production Schedule, the Fabrication Department implemented five production lines with a two-shift system for the hood repair process. This configuration completed repairs in 18 working days at a total cost of Rp99,580,294. The execution required 10 operators and 5 supervisors for hood-tubular assembly, 5 operators and 5 supervisors for painting, and 5 sets of welding and grinding equipment to enable parallel processing.

Estimated Production Cost with Repair

Due to the additional processes required for repairing defective products, production costs increased. Table 3.9 presents the total cost for producing 81 units.

Table 3.9 Estimated Production Cost with Repair

Cost Component	Cost
Total Cost of Normal Production	Rp203.929.019
Total Repair Cost	Rp99.580.294
Overall Cost	**Rp303.509.313**

Cost of Good Manufactured (COGM)

The cost of goods manufactured for the specialized vehicle's front engine hood is calculated by summing the unit production cost under normal conditions and the total repair cost allocated to each unit. The breakdown is shown in Table 3.10.

Table 3.10 Cost of Good Manufactured (COGM)

Production Process	Total Cost	Cost/Unit
Normal Production		Rp1.806.689
Defect Repair (81 unit)	Rp99.580.294	Rp1.229.386
COGM/Unit		**Rp3.036.075**

Thus, the COGM per unit of the front engine hood is Rp3,036,075, indicating an increase of Rp1,229,386 per unit compared to the initial cost of Rp1,806,689, as a result of the defect repair process.

3.4 Defect Causes and Repair Outcomes

Analysis of all 81 front engine hood units revealed two consistent defects: gaps between the hood and tubular frame (5-10 mm), and surface waviness (3-8 mm). These defects compromise both function and aesthetics, as noted by Groover (2019). Using a fishbone diagram (Figure 3.2) as recommended by Alijoyo and Fisabilillah (2020), we identified multiple root causes across five categories:

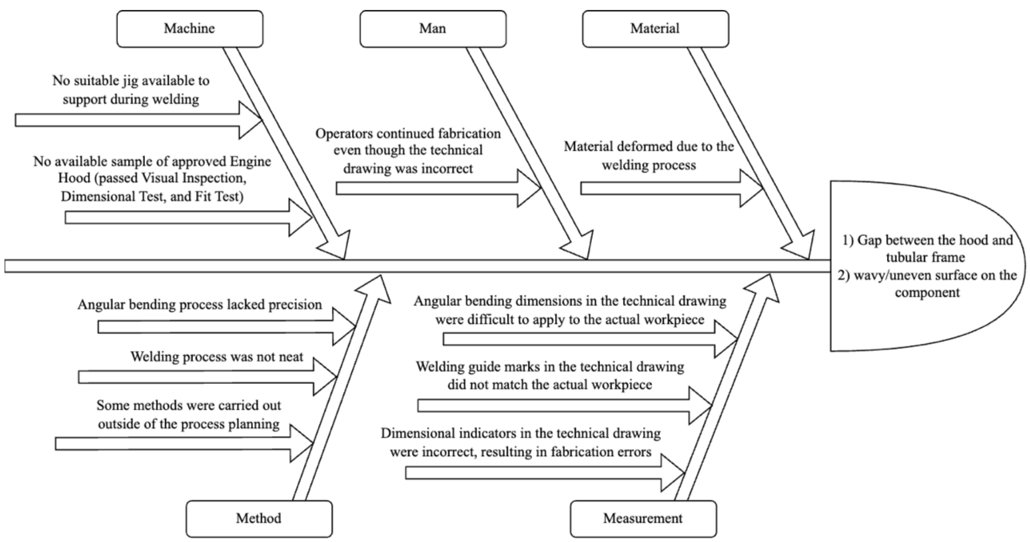

Figure 3.2 Fishbone Diagram of Product Defect Analysis

Machine-related factors included inadequate welding jigs, which led to component deformation, and the absence of approved reference samples. Human factors involved continuing fabrication despite known errors in technical drawings, compounded by weak coordination between design and production teams (Daniarsyah, 2021). Material issues stemmed from the 1.5 mm ST 37 steel's tendency to deform under welding heat (Sukarman, 2019). Methodological challenges were observed in achieving precise angular bends and maintaining consistent welding techniques (Sulistiono, 2021). Measurement errors arose from mismatches between technical specifications and actual manufacturing capabilities, compromising product quality (Gaspersz, 2004).

Among these, the absence of proper welding jigs was identified as the most critical root cause. Without adequate stabilization during welding, thermal stresses caused misalignment and surface irregularities—manifesting as gaps and waviness on the product. To mitigate these issues, this study recommends developing custom welding jigs, establishing approved reference samples, strengthening communication between design and production teams, implementing standardized welding procedures (Huda & Taufiqurrahman, 2022), formalizing fabrication methods, and introducing collaborative verification of technical drawings. These interventions would likely reduce defect rates, improve process efficiency, and eliminate substantial repair costs in future production (Riyanto, 2015).

4. Conclusion

This study successfully addressed all research objectives by analyzing the impact of defects in 81 specialized vehicle engine hoods. The cost analysis revealed that defect repairs increased manufacturing costs by 68.1% (from Rp1,806,689 to Rp3,036,075 per unit). Our time analysis showed that conventional repair would require 173 days, jeopardizing delivery schedules. The implemented multi-line optimization strategy with five production lines and a two-shift system reduced repair time by 89,6% to just 18 days, with only a 2.4% cost increase compared to a single-line approach. Root cause analysis identified the absence of proper welding jigs as the primary defect source, causing component deformation that resulted in gaps and uneven surfaces. This model demonstrates an effective balance between repair efficiency and cost management under tight deadlines, offering a practical framework for manufacturing industries facing similar challenges.

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