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Optimizing ship material productivity through the implementation of lean tools (value stream mapping)

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ABSTRACT

The shipbuilding industry must increase productivity to meet the demands of an increasingly competitive market. However, during ship production, various types of waste are still generated, resulting in low material utilization efficiency and increased production time. This study aims to optimize ship material productivity by applying lean manufacturing concepts through value stream mapping (VSM). The literature review in this study focuses on lean manufacturing concepts, the identification of seven types of waste, and analytical approaches such as the waste relationship matrix (WRM) and value stream mapping. The research used a quantitative descriptive design, collecting data through direct observation, interviews, and questionnaires distributed to respondents involved in the production process. The study found that the dominant waste categories are waiting, defects, overprocessing, transportation, and inventory. Through current-state and future-state map analyses, improvement proposals were developed, including implementing reuse molding, workflow arrangement, pre-kitting, layout optimization, and coordination between processes. The implementation of these improvements reduced non-value-added activities(or increased efficiency) by 26.7%shortened production lead time by 5.5%. Thus, value stream mapping has proven effective in improving material productivity in the fiberglass boat manufacturing process.

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1. INTRODUCTION

The shipbuilding industry plays a strategic role in supporting transportation and logistics. With growing market demand, companies must enhance production efficiency without compromising quality (Calvache et al., 2026). In the production of fiber-reinforced ships, however, non-value-added activities such as waiting,

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inefficient material handling, and repetitive tasks remain prevalent (Wijewickrama et al., 2025). Addressing these inefficiencies requires a systematic approach to waste reduction.

Lean manufacturing provides a proven framework for eliminating waste and improving efficiency (Rahardjo et al., 2023; Taş, 2024). Among its tools, Value Stream Mapping (VSM) is widely used to visualize material and information flow, identify non-value-added activities, and design future-state improvements (Teles & Abe, 2023). Complementing VSM, the Waste Relationship Matrix (WRM) enables prioritization of waste categories, ensuring that improvement efforts target the most critical inefficiencies.

While lean principles have been applied across industries, their integration in fiberglass shipbuilding remains limited. The novelty of this study lies in combining WRM and VSM to systematically identify, prioritize, and reduce waste in the production of fiberglass boats. Applied at PT. Blambangan Bahari Shipyard, this approach not only highlights dominant waste categories but also proposes tailored improvement strategies—such as reuse molding, workflow arrangement, pre-kitting, and layout optimization—that directly enhance material productivity and production efficiency.

2.RESEARCH METHODS

This study employed both primary and secondary data. Primary data were collected through questionnaires, direct observations, interviews, and reviews of production-stage documents. Secondary data included company operational records, employee statistics, and documentation of production methods.

The research stages were conducted as follows:

1. Identification of the ship production process.
2. Identification of waste using the Waste Relationship Matrix (WRM).
3. Distribution of questionnaires to workers.
4. Development of a current-state map.
5. Root cause analysis using a fishbone diagram.
6. Design of a future-state map.
7. Formulation of lean manufacturing improvement proposals.

Questionnaire Design and Validation

The WRM questionnaire was structured to capture the perceived influence among different types of waste. Each item was scored on a scale of 0, 2, or 4, representing no influence, moderate influence, or strong influence. To ensure validity, the questionnaire items were adapted from established WRM guidelines (Karningsih et al., 2019) and reviewed by two academic experts in manufacturing systems. Reliability was tested using Cronbach's Alpha, yielding a coefficient above 0.70, indicating acceptable internal consistency.

Sampling Criteria

Respondents were purposively selected for their direct involvement in ship production and supervisory or managerial responsibilities. This criterion ensured that participants possessed practical insights and long-term experience relevant to waste identification. Although the sample size was limited to five respondents, their roles—covering production supervision, workshop management, electrical division, finishing, and engineering—provided comprehensive coverage of critical production stages. The small but expert sample is justified because WRM analysis relies on informed judgment rather than large-scale statistical generalization.

WRM Scoring and Data Analysis

Responses were aggregated to construct the WRM matrix. Scores were converted into symbols (A = 10, E = 8, I = 6, O = 4, U = 2, X = 0) to quantify the strength of relationships among wastes. The total weighted scores determined the priority order of waste categories. Subsequent analysis integrated WRM results with value stream mapping (current-state and future-state maps) and fishbone diagrams to identify root causes and propose targeted improvements.

Respondent Profile

Table 1 summarizes the respondents' specifications:

Table 1. The respondents' specifications

No	Name	Position	Years of Experience
R1	Seno	Warehouse Section	4 years
R2	Karyono	Production Section	4 years
R3	Bambang	Electrical Section	8 years
R4	Imam Mujahid	Field Supervisor	6 years
R5	Zarkasi	Engineer	5 years

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3. RESULTS AND DISCUSSION

3.1 Fiber Boat Production Process

The fiber ship production process at PT. Blambangan Bahari Shipyard consists of 11 stages: design, hull & deck preparation, lamination & gelcoating, hull assembly, release & assembly, electrical installation, interior & accessories, machinery & equipment, finishing, launching & erection, and delivery& sea trial.

3.2 Waste Identification

Based on observation results and the questionnaire, several types of waste were identified in the fiber boat production process. Each of the 7 types of waste has its potential causes, but the identification results show that the dominant wastes include waiting, defects, transportation, overproduction, and inventory. Table 2 presents the identification of the 7 types of waste.

Table2. Waste identification

No	Waste type	Work explanation	Potential cause
1	Waiting	Workers are waiting for the resin that is being stirred or waiting for the fiber to be cut	Lack of coordination among workers
2	Inventory	Accumulation of ship molds in the production area	Lack of space to store used ship molds
3	Defect	Damage occurring to the ship molds stored in outdoor areas	Decreased wood quality and ship molds
4	Motion	Workers have to walk a long distance to take the lack of resin and catalyst because the storage location is disorganized	Non-ergonomic equipment layout
5	Transportation	Repeated transfer of fiber material from production area A to production area B	The material transfer flow is too long
6	Over-processing	The use of resin far exceeds the standard amount	Unclear standards for workers who laminate
7	Overproduction	Mixing too much resin, causing it to harden before it can be applied to the fiber	Lack of an estimated calculation of resin requirements per layer

3.3 Waste relationship matrix analysis

To determine the results of the questionnaire distribution, the total score is converted into relationship strength symbols (A, I, U, E, O, and X) according to the rules in Table 3.

Table3. Score Conversion Value to WRM Letter Grade

Range	Types of relationships	Symbol
17-20	Absolutely necessary	A
13-16	Especially important	E
9-12	Important	I
5-8	Ordinary closeness	O
1-4	Unimportant	U
0	No relation	X

The Waste Relationship Matrix (WRM) is used to determine how different types of waste in the production process are connected and how they influence one another. We calculate it by summing the relationship weights for each waste type based on respondents' ratings. The results are then used to assess the influence of each waste, helping identify which wastes should be prioritized for improvement. The formula for calculating the WRM is shown in the following equation Percentage = Total weight of waste/Total weight × 100%.

The WRM analysis results indicate that waste waiting has the strongest relationship with other waste types. This suggests that delays in the production process can trigger other wastes, such as defects, transportation issues, and inventory issues. Table 4 presents the results of the questionnaire distribution. Table 5 shows the conversion of numeric scores to letter grades, and Table 6 summarizes the overall results of the questionnaire distribution.

Table4. Questionnaire result weighting

F/T	WASTE

	O	I	D	M	T	P	W
O	__	18	12	24	30	0	20
I	10	_	16	20	24	0	18
D	12	14	_	18	0	0	22
M	14	15	10	_	10	0	0
T	18	20	0	0	_	8	0
P	0	0	20	0	0	_	10
W	20	18	22	24	26	14	_

Table5.WRM grade conversion

F/T	WASTE						
	O	I	D	M	T	P	W
O	_	A	I	A	A	X	A
I	I	_	E	A	A	X	A
D	I	E	_	A	X	X	A
M	E	E	I	_	I	X	X
T	E	A	X	X	_	O	X
P	X	X	A	X	X	_	I
W	A	A	A	A	A	E	_

Table6.Waste matrix value

F/T	WASTE								
	O	I	D	M	T	P	W	S	%
O	_	18	12	24	30	0	20	104	20.3
I	10	_	16	20	24	0	18	88	17.2
D	12	14	_	18	0	0	22	66	12.9
M	14	15	10	_	10	0	0	49	9.6
T	18	20	6	0	_	8	0	52	10.1
P	0	0	20	0	0	_	10	30	5.8
W	20	18	22	24	26	14	_	124	24.2
S	74	85	86	86	90	22	70	513	100.0
%	14.4	16.6	16.8	16.8	17.5	4.3	13.6	513	100.0

3.4 Current state map

The results of the current state map indicate that there are still relatively high non-value-added activities in the ship production process. The most significant waste occurs during the hull & deck preparation and hull assembly processes due to waiting times and inefficient material movement. Figure 3 illustrates the current state map at PT. Blambangan Bahari Shipyard.

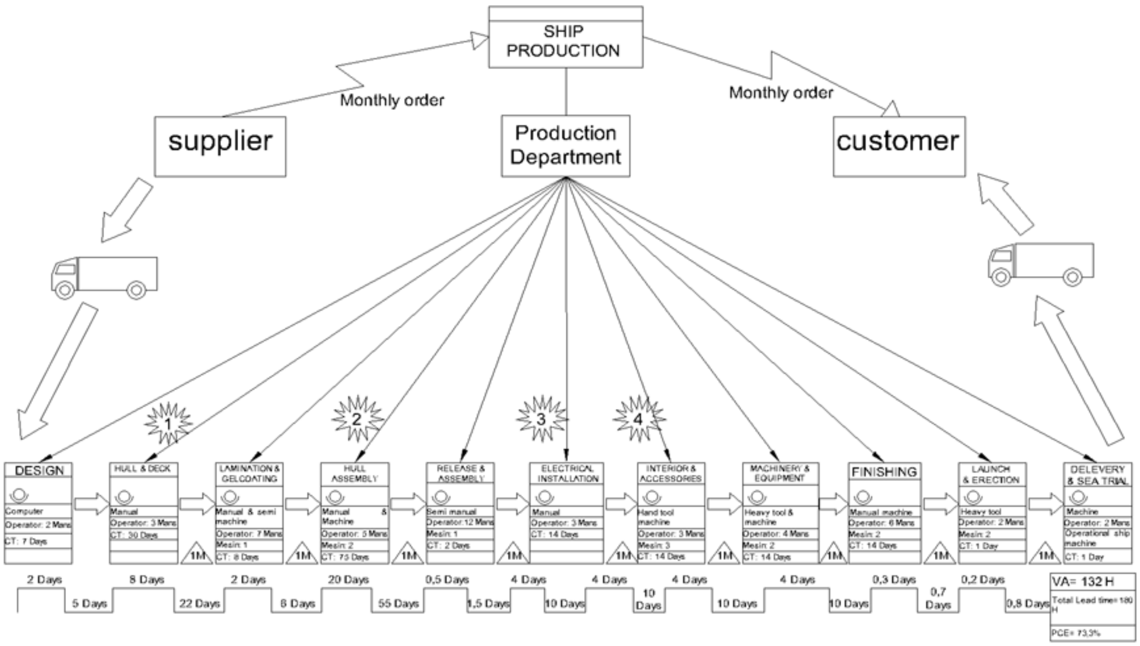

Figure 3. The current state map

The first step in calculating process efficiency is to recapitulate all the value-added working time and waiting time (non-value-added) from the fiber boat production stages based on field data.

Table 7.Production time

No	Process name	Total duration	Value added	Non-value added
1	Design	7 day	5 day	2 day
2	Hull & deck preparation	30 day	22 day	8 day
3	Lamination &gelcoating	8day	6 day	2 day
4	Hull assembly	75 day	55 day	20 day
5	Release& assembly	2 day	1,5 day	0,5 day
6	Electrical installation	14 day	10 day	4 day
7	Interior & accessories	14 day	10 day	4 day
8	Machinery & equipment	14 day	10 day	4 day
9	Finishing	14 day	11 day	3 day
10	Launching & erection	1 day	0,7 day	0,3 day
11	Delivery& sea trial	1 day	0,8 day	0,2 day
TOTAL		180 day	132 day	48 day

The total production lead time is 180 days, consisting of 132 days of value-added activities and 48 days of non-value-added activities. The comparison of the process efficiency value is as follows. Value add ratio or process cyle efficiency = 132/180 × 100%= 73,3%.

The ship production process at PT. Blambangan Bahari Shipyard recorded a total of 180 days, with 132 days of value-added activities and 48 days of non-value-added activities. The analysis results showed a ProcessCycle Efficiency (PCE) of 73.3%, which, according to the criteria of(Tohidi &Khedriliraviasl, 2012), exceeds the world-class manufacturing standard (>25%). This figure indicates an efficient production flow with minimal waste, although there is still an optimization opportunity of 26.7% to accelerate the production duration toward the company's ideal target.

3.5 Problem root cause analysis

Based on the value-added ratio or process cycle efficiency calculations, which show a value of 73.3%, the production flow at the shipyard is operating at a fairly good level of efficiency. Nevertheless, a non-value-added (NVA) activity amounting to 26,7% has been identified and categorized as waste. From the data results and the distribution of questionnaires to workers, the waste that emerged is as follows:

1. Waiting;The results of observations and questionnaires showed a waiting time of 24.2%, dominated by the hull assembly process and hull & deck preparation. As the point with the longest cycle time, this stage creates a domino effect that hinders subsequent activities. This inefficiency, exacerbated by unpreparedness in material supply, results in suboptimal utilization of labor and production facilities.
2. Defect;Dominant waste defects occur in the lamination and gelcoating processes due to uneven thickness, incomplete curing, and storing molds in open areas. These conditions require rework, which disrupts production flow and causes delays. The required strategic solutions include standardizing SOPs and providing adequate storage facilities to ensure quality before the assembly stage.
3. Overproduction;waste overproduction. Overproduction waste is identified during the mixing of resin and catalyst, as the amount exceeds the required amount due to inconsistencies in work standards. This non-value-added activity waste and the need for component readjustment, which directly prolongs production time and consumes labor resources.
4. Transportation;Waste transportation is identified at a material transfer distance of 20 meters between the mold area and the assembly area. This inefficient facility layout leads to frequent non-value-added mobilization, which lengthens production time and increases the risk of component damage during transfers.
5. Inventory;Waste inventory occurs due to the accumulation of materials and ship molds that are disorganized in open areas, which hinders stock monitoring. The buildup of components used immediately disrupts smooth material flow and prolongs production time due to inefficient storage management.

3.6 Proposed improvement

The proposed improvements were developed based on the identification of waste in the current state map and the root cause analysis using the fishbone diagram. The improvements focused on reducing non-value-added activities that frequently occurred during fiberglass boat production. The proposed actions included reusing suitable molding, implementing pre-kitting of materials to simplify work preparation, applying parallel work systems across several production stages, and rearranging the production layout to improve material-handling efficiency. Through these improvements, the production flow is expected to become smoother, and the existing waste can be minimized. Based on the waste identified on the current state map, the proposed improvements are as follows.

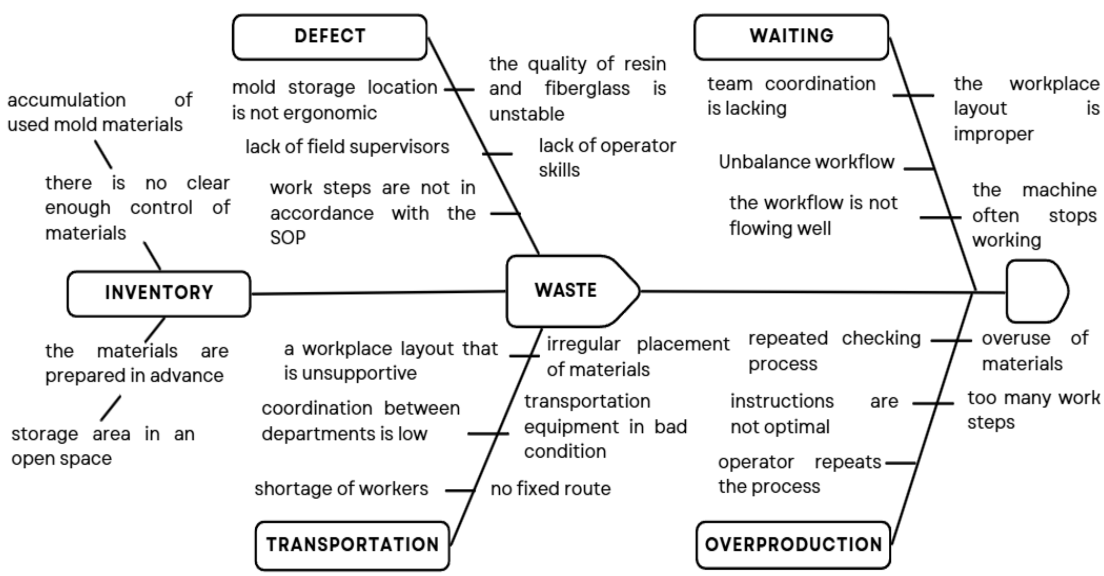

Figure 4. Fishbone diagram

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Recommendations for improvements to reduce non-value-added activities by 26.7% previously identified. The main focus of this proposal is to create a leaner production flow by synchronizing material procurement schedules, standardizing work instructions at critical points, and repositioning workflows to eliminate unproductive movements(Uz Zaman &Hosseinabad, 2021).

- Reuse of molding.
- Application of pre-kitting material.
- Parallel work between processes.
- Work process overlap.
- Rearrangement of production layout.

All of these proposals are then mapped onto the future-state value stream to estimate the efficiency achievable. In this scenario, the ship production cycle is expected to operate more efficiently while maintaining consistent product quality.In addition, the company is also advised to enhance coordination between departments and implement clearer work standards to reduce waste

In the next stage, an improvement schedule is created to make the flow of information more detailed and visible on the information board or kanban. Table 8 shows the improvement timeline for the flow in the current-state mapping that wastes time.

Table8. Improvement timeline

No	Process name	Improvement strategy	PIC	Target	Place	Time	Status
1	Preparation of hull & deck	Reuse old molds Minor mold repair Workspace layout rearrangement	Head production	Reducing excessive NVA	Molding area	1 month	Planning
2	Hull assembly	Determination of material path Preparation of SOP for material transfer improvement of coordination between teams	Head production	Stabilize the lead time to 68 days and prevent additional waiting time	Hull assembly area	1-2 months	Planning
3	Electrical installation	Application pre-kitting in installation materials Parallel work implementation in structural areas that are ready	Head of electrical division	Decrease 1 day NVA	Electrical installation area	2 month	planning
4	Interior & accessories	Implementation of overlap work Material arrangement closer to the installation point	Supervisor finishing	Decrease 1 day NVA	Finishing & interior area	2-3 months	Planning

3.7 Future State Map

The future state map shows a reduction in non-value-added activities and improvement in material flow. With the implementation of the proposed improvements, the production process becomes more efficient,reducing production lead time. Based on the expected future state value stream mapping, the PCE (Process Cycle Efficiency) or VAR (Value Add Ratio) of the shipbuilding process at PT. Blambangan Bahari Shipyard in the future condition is:

$$VAR/PCE = 130/165 \times 100\% = 78{,}8\%$$

The strategy to reduce lead time has yielded significant results; the total production duration now takes only 165 days. In addition, the value-added proportion has jumped to 78,8%, demonstrating that the production system has become much leaner without sacrificing stability in its core processes. The increase in efficiency is high enough, though not as high as that reported by Ponda et al., who reached up to 96,6% when applying the VSM method at a wheel manufacturer (Ponda et al., 2022). The estimated future state map has been talked over with the production supervisor and the head of the workshop at PT. Blambangan Bahari Shipyard. From the discussion, the suggested improvements seem doable since they don't require any tech changes or new machines, as explained in Table 9.

Table9. Reducing estimation

No	Suggested improvements	Estimation basis	Reduction
1	Reuse molding	Field observations, molding can be reused	6 days
2	Parallel work and pre-kitting	Analysis of processes that can be done simultaneously	1 days
4	Layout improvement	Reducing material transfer time	1 days
5	Inspection simplification	Reducing overprocessing activities	6 days
6	Production coordination	Reducing the waiting time between processes	1 days
TOTAL			15 days

The estimate of time reduction comes from field observations, discussions with the company, and analysis of non-value-added activities eliminated in the future-state map. This study only reached the stage of creating the future-state map, so it hasn't been implemented at the company yet. Therefore, the decrease in lead time remains an estimate based on lean manufacturing analysis and will need to be validated through implementation in future research. The results of reductions at several stages in shipbuilding are explained in Table 10 as follows.

Table10. Future state map result

No	Nama Proses	Lead Time	VA	NVA
1	Design	7	5	2
2	Hull &Deck preparation	24	20	4
3	Lamination&Gelcoating	8	6	2
4	Hull assembly	68	55	13
5	Disassembly & Assembly	2	1.5	0.5
6	Electrical installation	13	10	3
7	Interior & acessories	13	10	3
8	Machinery & equipment	14	10	4
9	Finishing	14	11	3
10	Launch & erection	1	0.7	0.3
11	Delivery& sea trial	1	0.8	0.2
Total		165	130	35
Current State Map total		180	132	48
Lead Time Reduction		15	2	13

The decrease in value-added time on the future state map doesn't mean there are fewer value-adding activities;it reflects improved process efficiency. Some suggested improvements, such as reusing suitable molds, implementing pre-kitting of materials, and performing tasks in parallel, can speed up activity completion without changing the function or quality of the production. So, it's the time spent on value-added activities that goes down, not the activities themselves.

The reduction of lead time across the four stages of this study follows the methodology developed by Arsyandi et al. (2024)for assembly process optimization, with a primary focus on improving workday efficiency by eliminating workflow bottlenecks and minimizing material waiting times. This approach aligns with the fundamental principles of lean manufacturing, as outlined byHines & Taylor (2000) in Going Lean, which emphasizes that strategies for effective time reduction focus on eliminating non-value-added activities. Accordingly, lead time reduction is applied to the first four stages: first, a 6-day reduction in the hull & deck preparation stage; second, a 7-day reduction in the hull assembly stage; third, a 1-day reduction in the electrical installation stage; and fourth, a 1-day reduction in the interior & accessories stage. Each process reduction to decrease lead time is implemented through informed planning, not speculation, and is carried out based on the

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identification of non-value-added activities on the current state map. Figure 5 explains the condition of the future state map.

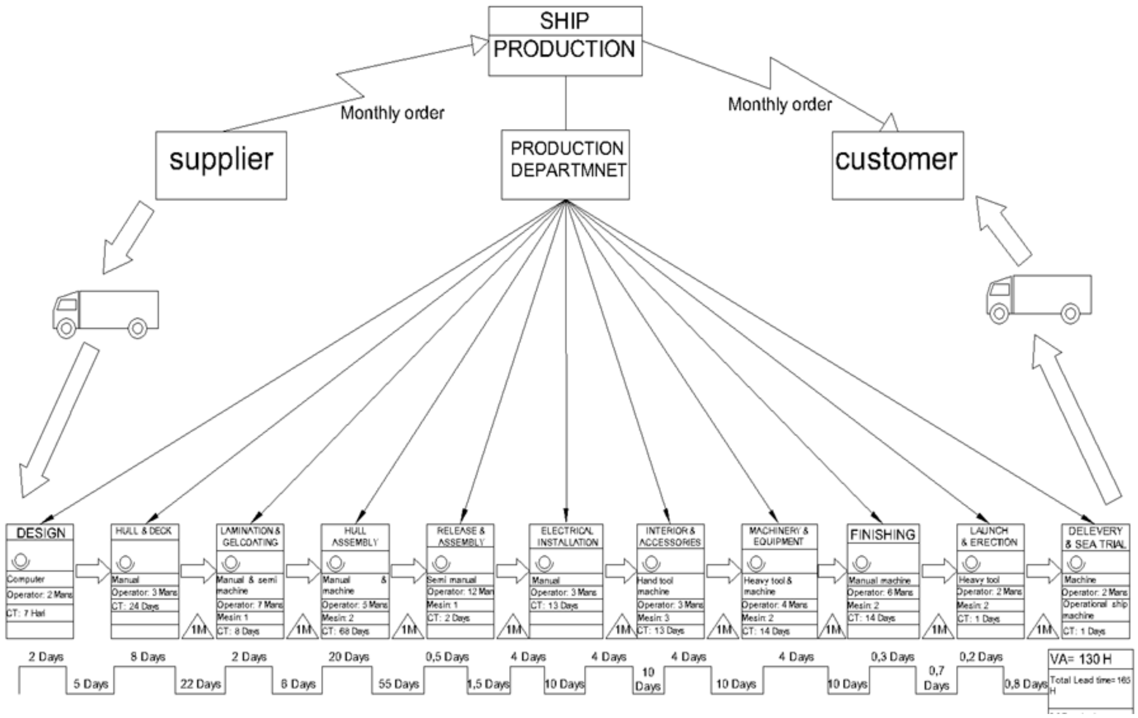

Figure 5. Future state map

4. CONCLUSION

This study identified five dominant wastes in fiberglass boat manufacturing—waiting, defects, overprocessing, transportation, and inventory—with waiting waste as the most critical due to frequent delays between production stages. Value stream mapping revealed significant non-value-added activities, particularly in hull preparation and assembly. By applying lean manufacturing tools, the process efficiency improved, with the PCE/VAR increasing from 73.3% to 78.8%.

The proposed future-state improvements—including mold reuse, material pre-kitting, parallel work, process overlap, and layout optimization—are expected to further reduce non-value-added activities and streamline production flow. While these improvements are based on systematic analysis, they remain proposed strategies that require implementation and validation in practice.

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