SEMARAK ILMU
PUBLISHING
202103268166(003316878-P)

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Optimizing Traditional Shipyard Industry: Integrating VSM and Sustainability Indicators for Continuous Improvement

Fitriadi Fitriadi[1], Ahmad Faisal Mohamad Ayob[2,*]

[1] Department of Industrial Engineering, Faculty of Engineering, Universitas Teuku Umar, 23681, Aceh Barat, Indonesia
[2] Program of Naval Architecture & Maritime Technology, Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia

ARTICLE INFO

Article history:
Received 8 May 2023
Received in revised form 28 December 2023
Accepted 3 March 2024
Available online 9 June 2024

Keywords:
Traditional Shipyard Industry; VSM; Sustainability Indicators; Continuous Improvement

ABSTRACT

Enhancing the sustainability of the Traditional Shipyard Industry necessitates continuous improvements in the production process to optimize efficiency and minimize waste. This study proposes suggestions for ongoing enhancements within the Traditional Shipyard Industry, integrating a Value Stream Mapping tool with Sustainability Indicators. These recommendations, applicable to traditional shipbuilding, aim to evaluate the production process's performance in measurable environmental, economic, and social terms. The integrated concept facilitates continuous monitoring of changes in Traditional Shipyards' shipbuilding systems. Employing a research methodology involving literature review, on-site fieldwork observations, and comprehensive discussions with stakeholders, including owners, management, employees, and operators in various Traditional Shipyards in Aceh, the findings suggest that this integrated approach not only provides directional guidance for improvement but also holds potential for fostering continuous advancements in ship production within Traditional Shipyards.

1. Introduction

Companies aiming to sustain a competitive edge must ensure the presence of a robust strategy for enhancing production performance. This involves continuous efforts to improve products, streamline production processes, and deliver exceptional customer service all geared towards evaluating and enhancing overall performance [1,2]. While many managers in the manufacturing industry often focus on identifying problems in the production process, it is crucial to recognize that continuous improvement is a holistic activity that should be implemented across all sectors and fields within the organization. This approach acknowledges the unique circumstances of each problem, addressing issues along the production line in an integrated manner with adherence to multiple improvement standards [3-5].

Additionally, the incorporation of a lean management system, particularly through the application of value stream mapping, proves instrumental in waste identification and elevating work-

* *Corresponding author.*
E-mail address: ahmad.faisal@umt.edu.my

https://doi.org/10.37934/araset.46.2.155170

in-process inventory levels [6]. Concurrently, research indicates that the gradual implementation of Kaizen leads to a decline in rejection rates, an upsurge in production, and heightened factory availability [7].

The Traditional Shipyard Industry (TSI) faces a distinctive set of challenges due to its unique production characteristics, including unconventional labor recruitment methods, basic production equipment, predominant use of wood materials, and ship designs dictated by the shipyard owner [8-12]. Moreover, the TSI operates on a make-to-order basis, with all ship designs exclusively determined by the TSI, utilizing wood as the primary raw material. This unconventional approach, coupled with non-standard working methods and the use of traditional techniques, heavily relies on human power in the production process, resulting in manufacturing waste that hampers shipbuilding performance in the TSI [13-18].

Research studies focusing on the performance of production processes in both modern and TSI sectors with a sustainability orientation are rare. The growing emphasis on organizational development, aimed at recognizing new realities and fostering continuous improvement, is essential for companies to attain superiority and competitiveness [19]. Competitive advantages can be achieved through innovative actions and novel technology implementations, emphasizing cost and differentiation advantages that seamlessly align with sustainable development [20].

While past improvements in shipyard performance primarily centered on technically oriented production processes, recent studies have explored conceptual improvement proposals, simulations, and direct maintenance. Ongoing research on shipyard improvement proposals, initiated in 2002, reflects a commitment to refining these strategies. For instance, Dibarra [13] advocates for shipyard enhancements through the 5S program to instigate changes in the work culture. Other studies prioritize performance improvements by focusing on the logistics process between fabrication panels and assembly stages, utilizing software simulations to formulate effective improvement frameworks [21]. The use of such software aids companies in managing facilities efficiently, reducing operational costs, and consequently enhancing overall performance [22]. Additional insights propose that shipyard repairs can be optimized by developing technology transfer concepts and models, minimizing investment losses, and boosting company productivity [23]. The efficiency of the Madura UKM shipyard's production process is targeted through an integrated approach, combining Simulation, Value Stream Analysis Tool (VALSAT), Response Surface Methodology (RSM), and Analytical Hierarchy Analysis (AHP) [24].

However, some studies, like Manea and Manea [25], focus solely on improving organizational performance based on internal identification and assessment, lacking detailed discussions on the workforce, customers, and suppliers. Similarly, Baso et al., [26], while presenting improved shipyard performance, omit details on sustainability-oriented improvements, excluding in-depth discussions on the workforce, customers, and suppliers. External factors are briefly addressed, highlighting partners, government policies, employee development, and shipyard clusters, with limited discussions on the technological environment, socio-cultural influences, and demographic factors. In contrast, Madrohim et al., [27], in their paper, emphasize enhancing the national shipbuilding industry's capability based on capacity-building factors and policy implementation, aligning with the goal of realizing Indonesia's defense sovereignty.

In light of the widespread aspiration to enhance company performance, numerous concepts and methods have emerged, revolving around the principle of continuous improvement. It is crucial to note that no single method is universally guaranteed to offer the optimal solution in all cases; rather, each application of concepts and methods comes with distinct strengths. Therefore, the thoughtful selection of concepts and methods for implementing the continuous improvement approach in addressing corporate challenges is paramount. The subsequent sections will delve into sustainability-oriented improvements.

Praharsi et al. [28] elucidate in their work that sustainable supply chain enhancements in traditional shipyards, employing the AHP method, can yield environmentally friendly shipbuilding proposals conducive to increased sales volume and business excellence. The manifold benefits of continuous improvement for business continuity are underscored, emphasizing the importance of exploring alternative and creative pathways grounded in quality improvement through continuous innovation [29].

Nascimento et al. [30] have successfully crafted a conceptual framework for addressing issues in the oil and gas sector through a gradual and continuous improvement approach, integrating lean production and Six Sigma. This integration facilitates a systematic and comprehensive problem-solving approach.

Recognizing the pivotal role of continuous improvement in augmenting the performance of the TSI, coupled with the expectations of the scientific community and practitioners, this paper aims to furnish recommendations for continuous improvement in the TSI. The proposed approach involves utilizing a Value Stream Mapping tool integrated with sustainability indicators, encompassing environmental, economic, and social systems. As articulated by Ehsan Vaezi, the identification of problem criteria through three sustainability indicators social, economic, and environmental serves as a foundation for offering performance-enhancing solutions.

2. Methodology

Selecting an appropriate research method is crucial to ensure that the research findings serve as robust scientific references and contribute to advancing theory and subsequent research endeavors [31]. In line with this consideration, a comprehensive literature review was conducted utilizing reputable journal articles sourced from platforms such as Google Scholar, ScienceDirect, IEEE Xplore, Emerald Insight, ResearchGate, Academia.edu, ProQuest, Taylor & Francis, and Elsevier. The search employed keywords including continuous improvement, sustainability indicators, value stream mapping, lean manufacturing, sustainable manufacturing, and shipyard. Figure 1 illustrates the methodological approach adopted in this study.

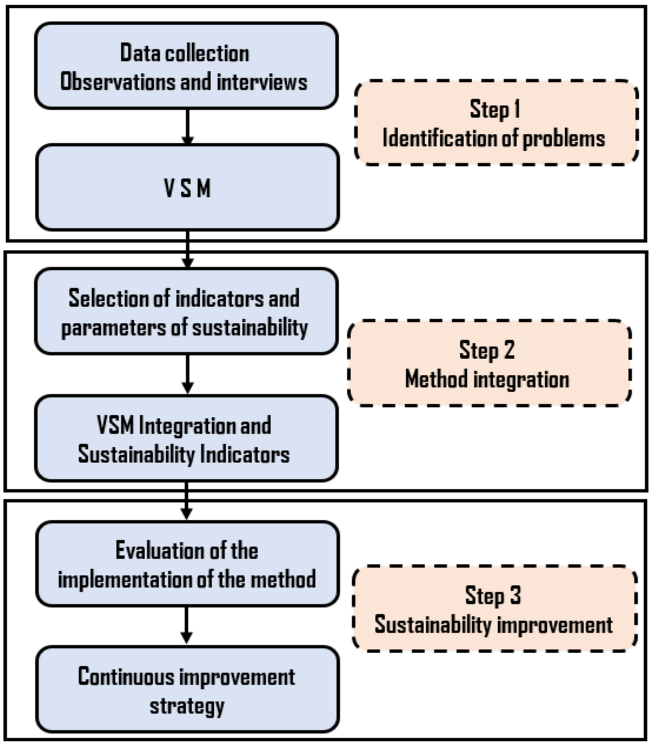

Fig. 1. Research methodology

This research employs a structured methodology encompassing multiple steps. Firstly, to address production line issues, the ship production process flow in the TSI is mapped using Value Stream Mapping (VSM). In the second step, parameters for sustainability indicators are selected and integrated with the mapping results from the initial step. The third step involves analyzing potential strategies for continuous improvement within the TSI. The integration of VSM and sustainability indicators is based on the model developed by Faulkner and Badurdeen [32]. To assess the application of the integrated VSM method with sustainable indicators, incorporating environmental, economic, and social parameters, a case study is conducted on five out of eleven traditional shipyards in West Aceh District [33].

In the first step, direct observations and interviews with traditional shipyard owners are conducted, yielding insights into operational conditions, incurred costs, and ship selling prices (refer to Tables 2 and 3). Observations on production lines provide cycle times for various ship volumes, as detailed in Table 4. Subsequently, standard time (ST) is determined in this step using Eq. (1) and (2) [34-39].

$$NT = CT \times Rf \quad (1)$$

$$ST = NT \times \frac{100}{100 - All} \quad (2)$$

ST represents standard time, and *Rf* signifies the rating factor, determined through direct observation of the TSI. These observations are then adjusted to the values specified in Table *All* [38]. *CT* denotes the cycle time of the shipbuilding process in a traditional shipyard. *ALL* is a concession obtained by directly observing operator activities at TSI, encompassing the operator's movements, physical condition, work facilities, and work environment. These observations are subsequently adjusted to the values in Table *All* [35,36,39], allowing for the derivation of the percentage value of *All* time.

The initial phase involves problem identification to distinguish between non-value-added (*NVA*) and value-added (*VA*) activities. *NVA* is determined through value flow mapping using the VSM method, revealing waste in shipyard production lines within the TSI. The mapping outcomes highlight waste categories such as Transportation (*T*), Motion (*M*), Inspection (*I*), Waiting (*W*), and Storage (*S*), as outlined in Table 6. Calculations for *NVA* and *VA* are performed using equations (3) and (4) [40,41].

$$NVA = T + M + I + W + S \tag{3}$$

$$VA = CT - NVA \tag{4}$$

The concluding task in the initial step is to ascertain the Process Cycle Efficiency (*PCE*) value, calculated through equation (5) [40,42,43].

$$PCE = \frac{VA}{CT}\ x\ 100\% \tag{5}$$

In Step 2 of this research method, we choose sustainability indicators suitable for the case study, focusing on environmental, economic, and social aspects. The subsequent phase involves selecting the appropriate parameters to integrate VSM and sustainability indicators, as illustrated in Table 1. The final step, Step 3, assesses the outcomes of integrating VSM and sustainability indicators. This evaluation serves as the basis for proposing potential strategies applicable to the TSI and offering recommendations for continuous improvement.

Table 1
Sustainability Indicators Applied in the TSI

Indicator	Parameter	Explanation
Environment	Raw material consumption	Utilization of raw materials occurs during a production cycle or a specific timeframe, including those ultimately disposed of as scrap.
	Energy consumption	Energy is utilized or expended within a specific production cycle or timeframe.
Economic	*CT*	The time required to execute work activities in each work element for producing one unit of a shipping product.
	Takt time	The time required to manufacture a single unit of a ship to fulfill customer demand.
	NVA	In the TSI, activities within the manufacturing process flow do not contribute value to the produced ships.
	VA	Activities in the production flow of the TSI contribute value to the produced ships.
	PCE	Comparison of VA and total lead time.
	Labor cost	The overall costs are borne by the TSI for remunerating workers' wages throughout the production process.
	Material cost	All expenses accrued during ship production encompass material prices, transportation costs, and storage expenses.
Social	Work environment risk	Health risks or workplace accidents within the work environment.

Attendance and absence days	Workers' attendance and absence fluctuate throughout the production process in traditional shipyards.
Salary level	The wage level for TSI workers.
Diversity ratio	The employee diversity measure was identified as a minority within the total organizational strength.

3. Results

The research findings comprise four key components: TSI operational conditions, VSM problem identification, integration of VSM and sustainability indicators, and the final section outlining a continuous improvement strategy. Case studies were conducted in five traditional shipyards, each representing different vessel volume sizes, including 3, 4, 8, 12, 15, and 20 GT.

3.1 Overview of Operations in the TSI

In TSI, the ship production process operates six days a week, eight hours per day. Operational conditions in traditional shipyards, obtained through observation and interviews in five shipbuilding industries, are presented in Table 2. The data encompasses various ship volume sizes: 3, 4, 8, 12, 15, and 20 GT. Takt time in Table 2 is derived by multiplying the available time with the total customer order time (demand per unit) for each ship volume size.

Table 3 details the correlation between ship volume size and incurred costs, encompassing raw materials, component costs, energy consumption, labor costs, and the selling price of ships in Indonesian Rupiah (IDR). The currency is abbreviated as IDR in currency exchange markets. This information was gathered through direct interviews with five shipyard owners. Table 3 presents the average calculations in the TSI, serving as the study's sample.

Table 2
TSI operational conditions

Ship size (GT)	Demand per unit (day)	Available time (hours)	Number of orders (units)	Total workforce (people)	Takt time (hours/unit)
3	40	8	8	3	320
4	60	8	8	3	480
8	90	8	5	6	720
12	120	8	3	8	960
15	150	8	3	12	1200
20	180	8	2	15	1440

Table 3
The TSI raw material and component costs, energy consumption, labor, and ship-selling prices

Ship size (GT)	Cost of Raw Materials (IDR)	Cost of energy consumption (IDR)	Labor costs (IDR)	Selling Price (IDR)
3	87,839,600	3,485,000	35,180,000	250,000,000
4	126,980,000	4,230,000	52,400,000	350,000,000
8	183,860,000	5,240,000	73,520,000	500,000,000
12	260,160,000	6,940,000	106,320,000	750,000,000
15	284,320,000	9,340,000	110,620,000	800,000,000
20	318,540,000	12,940,000	126,920,000	900,000,000

3.2 VSM-Based Problem Recognition

Continuous improvement in the TSI through integrated VSM with Sustainability Indicators initiates with problem identification using the VSM tool, encompassing four stages: measuring *CT* in the first stage, determining *ST* in the second stage, conducting Process Activity Mapping (PAM) in the third stage, and establishing the current *PCE* condition in the final stage.

3.2.1 *CT* assessment

Table 4 below displays the *CT* for each work activity corresponding to various ship volume sizes. This data was acquired through direct observation in the TSI by recording the duration of each work activity in the shipbuilding process. The observation results identified 17 work activities, which were subsequently coded alphabetically to streamline the calculation and documentation process. The alphabetical order of the codes in Table 4 reflects the sequence of the shipbuilding process in the TSI.

Table 4
Assessing CT for Shipbuilding in the TSI

Work activity	Code	*CT* (hours)					
		3 GT	4 GT	8 GT	12 GT	15 GT	20 GT
Ship keel making	A	6.4	9.6	14.4	19.2	24	28.8
Construction of the bow	B	5.4	8.1	12.2	16.2	20.3	24.3
Installation of the bow	C	3.5	5.3	7.9	10.5	13.1	15.8
Manufacture of stern high	D	4	24.5	36.8	50	62.5	75
Installation of stern height	E	2.4	4	5.4	7	9	11
Installation of basic frames	F	62	93	139.5	186	232.5	279
Installation of canopy frames	G	22.5	33.8	50.6	67.5	84.4	101.3
Installation of the lower hull skin	H	18	27	40.5	54	67.5	81
Installation of the hull skin / upper wall	I	25	37.5	54	72	90	108
Deck making	J	26	39	57	76	95	114
Hatch making	K	18	23	34.5	46	57.5	69
Manufacture of ship decks	L	24	36	55	73.3	91.7	110
Sanding and patching	M	16.5	24.8	37.1	49.5	61.9	70
Installation of plastic sheeting	N	4.53	6.8	12.5	15.4	19	23.1
Aluminum zinc installation	O	32	40	55	73	92	107
Painting	P	18	21	37	49.3	61.7	82
Installation of engines, propellers, and rudders	Q	31	46.5	69.8	93.0	116.3	139.5
Sum	-	319.2	478.8	719.1	958.5	1198.1	1438.5

3.2.2 Analyzing ST in traditional shipyard operations

Utilizing the data in Table 4, the standard shipbuilding time in the TSI for each ship volume size can be determined through equations 1 and 2. The calculation results are presented in Table 5, outlined as follows.

Table 5
Assessment of Shipbuilding *ST* in the TSI

Ship size (GT)	*CT* (hours)	*RF*	*All*	*NT* (hours)	*ST* (hours)
3	319.2	1.11	12.8	354.3	406.4
4	478.8	1.25	11.5	598.6	676.3
8	719.1	0.98	10.5	704.7	787.4
12	958.5	1.00	11.8	958.5	1086.7
15	1198.1	0.88	13.6	1054.4	1220.3
20	1438.5	0.98	15.1	1409.7	1660.5

3.2.3 Analyzing process activities through PAM

PAM involves identifying *NVA* activities through direct observation in the TSI, being an integral part of VSM. This tool aids in discerning waste within the TSI. Table 6 illustrates the correlation between ship products and *NVA* time identification data, encompassing Transportation (*T*), Movement (*M*), Inspection (*I*), Waiting (*W*), and Storage (*S*), based on ship volume size. The data is collected through direct observation in the TSI. *NVA* and *VA* values are computed using equations 3 and 4, with the results presented as follows.

Table 6
Assessing *NVA* Aspects in 3 GT Ship Production at TSI

Code	*CT* (hours)	*T* (hours)	*M* (hours)	*I* (hours)	*W* (hours)	*S* (hours)	*NVA* (hours)	*VA* (hours)
A	6.4	0.10	0.08	0.05	0.20	0.70	1.13	5.27
B	5.4	0.20	0.10	0.10	0.25	1.50	2.15	3.25
C	3.5	0.10	0.05	0.05	0.20	0.50	0.90	2.60
D	4.0	0.10	0.05	0.10	0.10	1.00	1.35	2.65
E	2.4	0.10	0.05	0.05	0.20	0.50	0.90	1.50
F	62.0	0.25	0.20	0.07	0.50	2.00	3.02	58.98
G	22.5	0.35	0.20	0.05	0.50	2.00	3.10	19.40
H	18.0	0.40	0.20	0.10	1.00	2.50	4.20	13.80
I	25.0	0.10	0.20	0.10	1.00	2.50	3.90	21.10
J	26.0	0.10	0.15	0.10	0.50	2.00	2.85	23.15
K	18.0	0.25	0.10	0.10	0.25	2.00	2.70	15.30
L	24.0	0.30	0.10	0.05	0.50	2.00	2.95	21.05
M	16.5	0.25	0.10	0.01	0.75	2.00	3.11	13.39
N	4.5	0.20	0.10	0.05	0.25	1.50	1.50	3.03
O	32.0	0.30	0.10	0.05	1.00	1.30	2.75	29.25
P	18.0	0.25	0.10	0.01	2.00	2.50	4.86	13.14
Q	31.0	0.50	0.10	0.01	0.50	2.50	3.61	27.39
Sum	319.23	3.85	1.98	1.05	9.70	29.00	44.98	274.25

Calculate *NVA* and *VA* values for additional ship sizes using the data in Table 6. These results, as presented in Table 6, are subsequently summarized to provide overall identification results for all ship volume types, as illustrated in Table 7.

Table 7
Findings of *NVA* Identification in Ship Production at TSI

Ship size (GT)	*CT* (hours)	*T* (hours)	*M* (hours)	*I* (hours)	*W* (hours)	*S* (hours)	*NVA* (hours)	*VA* (hours)
3	319.2	3.9	2.0	1.1	9.7	29.0	45.6	273.7
4	478.8	9.9	3.9	2.5	17.0	43.5	76.7	402.2
8	719.1	16.6	13.9	11.2	21.9	45.0	108.6	610.5
12	958.5	21.8	21.9	17.0	33.2	40.0	133.8	824.7
15	1198.1	24.8	20.4	21.6	41.5	44.5	152.8	1045.4
20	1438.5	32.5	30.5	32.8	45.5	49.0	190.3	1248.3

3.2.4 Analyzing the existing situation of PCE

Utilize Equation 5 to compute the current condition *PCE* value for each vessel volume size, relying on the *VA* calculation results presented in Table 7. The outcomes of these calculations are depicted in Table 8, outlined as follows.

Table 8
PCE of current conditions

Ship size (GT)	*CT* (hours)	*VA* (hours)	*PCE* (%)
3	319.2	273.7	85.72
4	478.8	402.2	83.98
8	719.1	610.5	84.90
12	958.5	824.7	86.04
15	1198.1	1045.4	87.25
20	1438.5	1248.3	86.77

Figure 2 illustrates the correlation between *CT*, *VA*, and *PCE* concerning ship size measured in GT. The graphed data reveals that as ship size increases, both *CT* and *VA* also increase, albeit with a slight decline in *PCE* for larger ship sizes. For instance, a ship with 3 GT exhibits a *CT* of 319.2 hours, *VA* of 273.7 hours, and *PCE* of 85.72%, whereas a ship with 20 GT has a *CT* of 1438.5 hours, *VA* of 1248.3 hours, and *PCE* of 86.77%. These findings underscore the significant interplay between ship size and performance factors like *CT*, *VA*, and *PCE*, offering valuable insights for shipbuilders and designers aiming to optimize shipbuilding production efficiency.

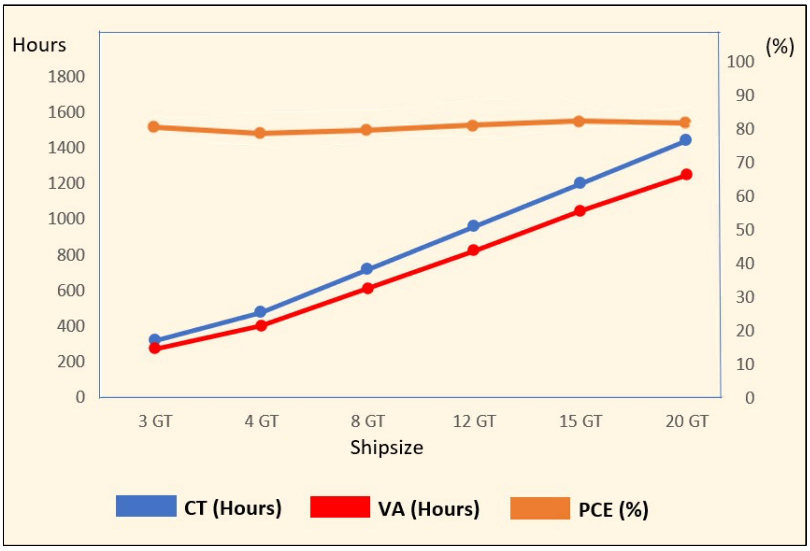

Fig. 2. Relationship among CT, VA, and PCE in relation to ship size

3.3. Integrating VSM with Sustainability Indicators

The integration of VSM and sustainability indicators involves linking the outcomes of problem identification using VSM with the results obtained from observations and interviews utilizing sustainability indicators, as outlined in Table 1. This stage is delineated based on sustainability indicators, encompassing three facets: environmental indicators, economic indicators, and social indicators.

3.3.1 Parameters for environmental indicators

The environmental indicators used for ship production in the TSI encompass raw material consumption and energy consumption. Through observations and interviews, it is evident that wood is the primary material for shipbuilding in the TSI, and the sources of wood raw materials are depleting and challenging to obtain [8]. This indicates that, concerning the source of raw materials, the sustainability of the TSI is not yet ensured. However, in terms of raw material consumption efficiency, the TSI demonstrates effectiveness and efficiency. As per Table 3, the comparison and percentage of costs incurred for raw materials concerning shipping products are 1:2.85 and 35.63%, respectively. The ratio and percentage comparison of raw material consumption to ship products remains relatively low, below 50% [44,45]. This suggests that the TSI optimally utilizes raw materials, given the low occurrence of scrap in the production process. Consequently, the TSI demonstrates the responsible use of raw material sources from plantations, maintaining terrestrial ecosystems [46]. Therefore, based on the parameter of raw material consumption, the TSI aligns with sustainability indicators.

Regarding the energy consumption parameter in environmental indicators for the ship production process in the TSI, observational and interview data indicate that the energy consumption value is still low. This is attributed to the fact that the percentage of costs incurred for energy use, compared to the product value, is only 1.2%. The limited energy consumption is primarily allocated to the six engines used in ship production in traditional shipyards. This situation signifies that, from an environmental standpoint, the TSI's energy consumption parameters are deemed sustainable.

3.3.2 Parameters for economic indicators

To gauge the sustainability of the TSI through economic indicators, the parameters encompass *CT*, Takt time, *NVA*, *VA*, *PCE*, labor costs, and material costs. As indicated in Tables 2 and 4, the shipbuilding process in the TSI adeptly fulfills customer demands. This is evidenced by the comparison between *CT* and Takt time (*CT* A-Q ≤ Takt Time). Figure 3 visually illustrates the discussed scenario, providing a clearer and more intuitive understanding of the concept. Consequently, based on the *CT* and Takt time parameters, the TSI aligns with sustainability indicators.

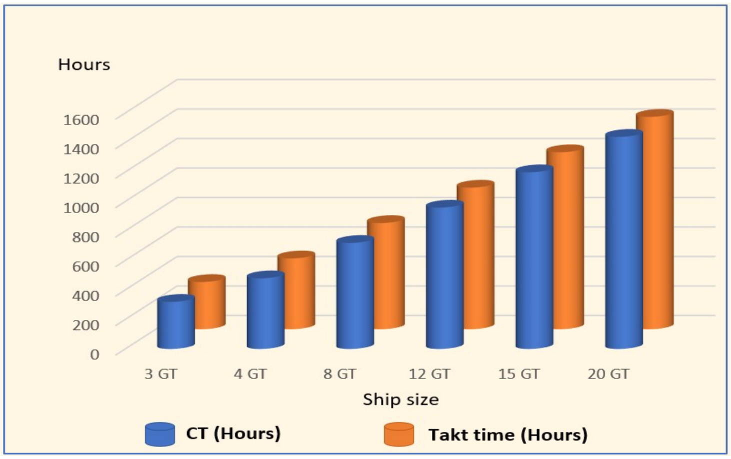

Fig. 3. Visual Representation Comparison of CT and Takt Time

NVA, *VA*, and *PCE* parameters within economic indicators for ship production in the TSI are interconnected. As depicted in Table 7, non-value-added activities persist in TSI ship production, evident in the time allocated to *NVA* in the process. Notably, the lowest *NVA* time value was recorded in the production of 3 GT vessels at 45.6 hours, while the highest *NVA* was observed in the production of 20 GT vessels, totaling 190.3 hours. The escalation of *NVA* values correlates directly with the augmentation of ship volume size. The comparison of the average percentage of *NVA* and *VA* in TSI ship production stands at 16.6%. *PCE* parameters, detailed in Table 8, illustrate the inefficiency of the ship production process in the TSI. Figure 4 visually encapsulates this inefficiency, providing a succinct representation for easy interpretation. Consequently, based on *NVA*, *VA*, and *PCE* parameters, the TSI falls short of sustainability indicators, necessitating improvement.

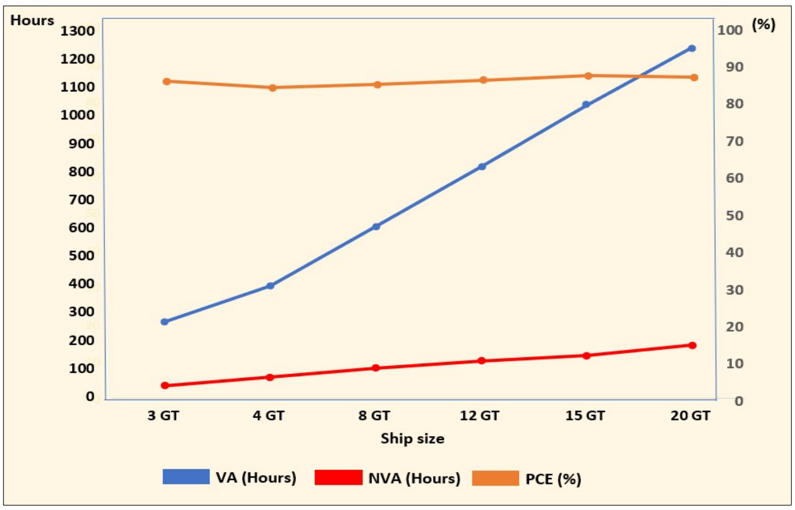

Fig. 4. Relationship among VA, NVA, and PCE in relation to Ship size

Labor and material cost parameters in traditional shipyard economic indicators align with sustainability indicators. Both labor and material costs demonstrate minimal waste, with labor costs accounting for 14.3% and material costs for 35.6% in comparison to the value of shipped products.

3.3.3 Parameters for social indicators

The parameters assessing sustainability in the TSI based on social indicators encompass work environment risk, attendance, absence, salary levels, and diversity ratio. An optimal work environment, with minimal health and safety risks, is crucial for enhancing worker productivity [44]. Interviews conducted in the TSI revealed the absence of work accidents that could jeopardize workers' health, despite the industry's reliance on manual labor. Skilled workers, equipped with knowledge passed down through generations, contribute to this safety record. Thus, regarding work environment risk parameters, the TSI aligns with sustainability indicators.

In the TSI, both attendance and absence parameters meet sustainability indicators during the ship production process. Every worker consistently participates in each production process, with no instances of absenteeism. Additionally, the salary level parameter satisfies sustainability indicators, as there is no dissatisfaction among workers regarding their earnings. The payment method, based on a per-unit ship contract, ensures contentment. According to research findings, the diversity ratio parameter indicates a homogenous workforce of male workers hired based on kinship, resulting in a harmonious organizational structure without significant disruptions.

3.4. Developing Strategies for Continuous Improvement

The integration of VSM and sustainability indicators in the TSI revealed critical parameters within sustainability indicators, emphasizing the primary objective of continuous improvement to enhance competitiveness, superiority, and sustainability. Recognizing the areas where parameters fall short of sustainability indicators is pivotal in developing an effective continuous improvement strategy. Table 9 presents comprehensive recommendations for continuous improvement strategies tailored to each indicator and parameter.

Table 9
Recommendations for ongoing improvement strategies

Indicator	Parameter	Ongoing improvement strategies
Environment	Raw material consumption	- Enhance workforce proficiency and skills through training to mitigate the risk of failures in raw material processing within the TSI, consequently minimizing scrap production. - Implement technological upgrades for cutting tools and processing equipment to reduce the risk of failures in raw material processing within the TSI, resulting in decreased scrap production. - Establish dedicated storage areas for waste or scrap, promoting cleanliness and a conducive working environment in and around the TSI.
	Energy consumption	- Implement technological upgrades for process equipment to lower energy

		consumption, specifically reducing fuel usage. - Conduct regular and scheduled maintenance for process equipment to enhance overall performance, resulting in improved energy efficiency.
Economic	*CT* dan Takt time	- Optimize the production line and workspace layout. - Implement the 5S work principles comprehensively and systematically.
	NVA, *VA* dan *PCE*	- Revise the arrangement of tool and equipment storage. - Restructure raw material storage. - Upgrade technology by incorporating advanced processing tools to reduce reliance on manual labor. - Implement a schedule for the efficient utilization and procurement of raw materials to minimize waiting times.
	Labor cost	- Revise work schedules and consider altering the wage payment method to align with either working hours or working days.
	Material cost	- Enhance workforce skills through training to minimize the risk of failure in raw material processing within the TSI, thereby optimizing raw material utilization. - Upgrade technology for using cutting tools and other production equipment to mitigate the risk of failure in raw material processing, leading to optimized raw material usage. - Implement recycling initiatives for waste and scrap to enhance their resale value.
Social	Work environment risk	- Promote awareness and adherence to the use of personal protective equipment (PPE) through effective socialization. - Enhance the involvement and supervision of work activities by TSI leaders or owners. - Establish an occupational health and safety management system as a proactive planning and control measure.
	Attendance and absence days	Incentivize employees with exemplary attendance through a reward system.
	Salary level	Revise the wage payment system to align with either working hours or working days.
	Diversity ratio	Enhance workplace communication, organize regular recreational activities, improve the compensation and rewards system, and provide facilities to support employees' hobbies.

The strategies outlined in Table 9 aim to minimize waste in ship production within the TSI. Given the inadequacies in meeting sustainability indicators, the primary focus lies on economic indicators, specifically *NVA*, *VA*, and *PEC* parameters. The sustainability of the TSI hinges on the effective implementation of these continuous improvement recommendations. Thus, it is anticipated that these suggestions will guide ongoing efforts to enhance ship production within the TSI, ensuring competitiveness and sustained advantages in the industry.

4. Conclusions

The evaluation of continuous improvement within the TSI through the integration of VSM and sustainability indicators reveals suboptimal performance in ship production. The overall *PEC* stands at an average of 85.78%, with individual PEC values for ship sizes varying. Despite the apparent cycle time and standard time for ship production, including *NVA* time elements, the *NVA* time components, such as transportation, motion, inspection, waiting, and storage, contribute to this suboptimal performance. Cycle times and standard times for different ship sizes further highlight the inefficiencies in the TSI production process.

The research emphasizes the integration of VSM with measurable sustainability indicators, encompassing environmental, economic, and social dimensions. Environmental indicators include raw material and energy consumption, economic indicators consist of various parameters like *CT*, Takt Time, *NVA*, *VA*, *PCE*, labor costs, and material costs, while social parameters cover work environment risks, attendance and absenteeism rates, salary levels, and diversity ratios.

Given the integration results falling short of sustainability indicators, the focus of continuous improvement strategies centers on economic indicators, specifically *NVA*, *VA*, and *PCE*. The recommendations propose measures such as reorganizing tool and equipment storage, optimizing raw material storage, upgrading technology, and implementing better scheduling practices. These improvements aim to enhance the economic aspects of ship production, fostering sustainability and competitiveness for the TSI in the market.

Acknowledgment

We extend our heartfelt appreciation to Universitas Teuku Umar, Universiti Malaysia Terengganu, and the Aceh Human Resources Development Agency for their invaluable support in facilitating my studies, research endeavors, and publications. Our sincere thanks go to the individuals and organizations whose time and expertise greatly contributed to the success of this project. Gratitude is also extended to the diligent reviewers for their insightful suggestions.

References

[1] Zhou, Ji, Peigen Li, Yanhong Zhou, Baicun Wang, Jiyuan Zang, and Liu Meng. "Toward new-generation intelligent manufacturing." *Engineering* 4, no. 1 (2018): 11-20. https://doi.org/10.1016/J.ENG.2018.01.002

[2] Mrugalska, Beata, and Magdalena K. Wyrwicka. "Towards lean production in industry 4.0." *Procedia engineering* 182 (2017): 466-473. https://doi.org/10.1016/J.PROENG.2017.03.135

[3] Randhawa, Jugraj Singh, and Inderpreet Singh Ahuja. "5S–a quality improvement tool for sustainable performance: literature review and directions." *International Journal of Quality & Reliability Management* 34, no. 3 (2017): 334-361. https://doi.org/10.1108/IJQRM-03-2015-0045/FULL/PDF

[4] Pambreni, Yuni, Ali Khatibi, S. Azam, and J. J. M. S. L. Tham. "The influence of total quality management toward organization performance." *Management Science Letters* 9, no. 9 (2019): 1397-1406. https://doi.org/10.5267/J.MSL.2019.5.011

[5] McLean, Richard S., Jiju Antony, and Jens J. Dahlgaard. "Failure of Continuous Improvement initiatives in manufacturing environments: a systematic review of the evidence." *Total Quality Management & Business Excellence* 28, no. 3-4 (2017): 219-237. https://doi.org/10.1080/14783363.2015.1063414

[6] Wai, Tan Hong, Khairur Rijal Jamaludin, Halim Shah Hamzah, and Sek Chun Chong. "Manufacturing inventory performance enhancement using lean management." *Journal of Advanced Research in Business and Management Studies* 8, no. 2 (2017): 1-6.

[7] Al-shehhi, Nawaf, and Khairur Rijal Jamaludin. "Kaizen event applied to aluminum manufacturing–Case study." *Journal of Advanced Research in Business and Management Studies* 8, no. 2 (2017): 45-49.

[8] Rizwan, Thaib, Ayana Rizki, Umiralaska Salsabila, Muhammad Muhammad, Riyan Maulana, Makwiyah A. Chaliluddin, Junaidi M. Affan, Razali Thaib, Suhendrianto Suhendrianto, and Yusrizal Muchlis. "Literature review on shipyard productivity in Indonesia." *Depik* 10, no. 1 (2021): 1-10. https://doi.org/10.13170/depik.10.1.18712

[9] DiBarra, Camilla. "5S—A Tool for Culture Change in Shipyards." *Journal of Ship Production* 18, no. 03 (2002): 143-151. https://doi.org/10.5957/jsp.2002.18.3.143
[10] Cil, Ibrahim, Fahri Arisoy, Hilal Kilinc, Ekrem Özgürbüz, Ahmet Yunus Cil, and Erkan Uysal. "Challenges and trends in shipbuilding industry: digitization of SEDEF shipyard in Turkey." In *2021 5th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, pp. 799-804. IEEE, 2021. https://doi.org/10.1109/ISMSIT52890.2021.9604757
[11] Fitriadi, Fitriadi, and Ahmad Faisal Mohamad Ayob. "Continuous Improvement Strategy in Traditional Shipyard Industry: A Holistic Approach towards Sustainability." *Journal of Optimization in Industrial Engineering* 16, no. 1 (2023): 255-268. https://doi.org/10.22094/JOIE.2023.1982419.2052
[12] Fitriadi, Fitriadi, and Ahmad Faisal Mohamad Ayob. "Enhancing Production Process Performance in Traditional Shipyards: An Integrated Approach for Waste Identification and Performance Optimization." *Journal of Optimization in Industrial Engineering* (2023). https://doi.org/10.22094/JOIE.2023.1998418.2109
[13] Lai, EdwinTanHock, FlorenceNgJia Yun, IvanC Arokiam, and JohnHengAik Joo. "Barriers affecting successful lean implementation in Singapore's shipbuilding industry: a case study." *Operations and Supply Chain Management: An International Journal* 13, no. 2 (2020): 166-175. http://doi.org/10.31387/oscm0410260
[14] Praharsi, Yugowati, Mohammad Abu Jami'in, Gaguk Suhardjito, and Hui-Ming Wee. "Lean management and analysis-An empirical study of a traditional shipbuilding industry in Indonesia." In *Proceedings of the International Conference on Industrial Engineering and Operations Management*. Toronto: IEOM Society International, 2019.
[15] Fitriadi, Fitriadi, and Ahmad Faisal Mohamad Ayob. "Identifying the Shipyard Waste: An Application of the Lean Manufacturing Approach." *International Journal of Global Optimization and Its Application* 1, no. 2 (2022): 100-110. http://doi.org/10.56225/IJGOIA.V1I2.19
[16] Fitriadi, Fitriadi, A. F. Ayob, Muzakir Muzakir, A. Saputra, I. Pamungkas, K. Hadi, and H. T. Irawan. "Identification of waste for shipyard through lean manufacturing approach." In *AIP Conference Proceedings*, vol. 2484, no. 1. AIP Publishing, 2023. https://doi.org/10.1063/5.0110526/2879703
[17] Xue, Lei, Guofu Shi, Dashuang Dai, and Yizhuang Xu. "Two-stage efficiency structure analysis model of shipbuilding based on driving factors: the case of Chinese shipyard." *Open Journal of Social Sciences* 8, no. 02 (2020): 182. http://doi.org/10.4236/jss.2020.82015
[18] Sulaiman, Sulaiman, Eko Julianto Sasono Eko Julianto Sasono, Sulistiyono Susilo Sulistiyono Susilo, and Suharto Suharto. "Factors Affecting Shipbuilding Productivity." https://iaeme.com/Home/article_id/IJCIET_08_07_103
[19] Souza, João Paulo Estevam, and João Murta Alves. "Lean-integrated management system: A model for sustainability improvement." *Journal of cleaner production* 172 (2018): 2667-2682. http://doi.org/10.1016/J.JCLEPRO.2017.11.144
[20] Amran, Mohd Effendi, and Mohd Nabil Muhtazaruddin. "Renewable Energy Optimization Review: Variables towards Competitive Advantage in Green Building Development." *Progress in Energy and Environment* (2019): 1-15.
[21] Dev, A. K., and Z. K. Fung. "Simulation of hull panel logistics improvement in a shipyard." In *Proceedings of the International Conference on Computer Applications in Shipbuilding, Amsterdam*. 2019. http://doi.org/10.3940/RINA.ICCAS.2019.1.8
[22] Wang, Dan, Terh Jing Khoo, and Zhangfei Kan. "Exploring the application of digital data management approach for facility management in Shanghai's high-rise buildings." *Progress in Energy and Environment* (2020): 1-15.
[23] Firmansyah, M. R., and W. Djafar. "Conceptual model for transfer of technology in a shipyard." *International Journal of Engineering and Science Applications* 4, no. 1 (2017): 43-50. https://doi.org/10.25042/epi-ije.022018.08
[24] Estiasih, Soffia Pudji, Bambang Sutejo, and Putra Wing Hendroprasetyo Akbar. "Lean and green manufacturing design at SMES's madura shipyard with value stream mapping tool and simulation model." *LEAN AND GREEN MANUFACTURING DESIGN OF SMES'S MADURA SHIPYARD WITH VALUE STREAM MAPPING TOOL AND SIMULATION MODEL* 8, no. 9 (2017): 194-202.
[25] Manea, Emil, and Mihaela Greti Manea. "The risk concept and the impact on the organizational performance of maritime shiprepairs shipyards." In *Advanced Engineering Forum*, vol. 34, pp. 300-308. Trans Tech Publications Ltd, 2019. http://doi.org/10.4028/WWW.SCIENTIFIC.NET/AEF.34.300
[26] Baso, Suandar, and Andi Dian Eka Anggriani. "Strategy for improving the competitiveness of shipyards in the Eastern part of Indonesia." *Jurnal Ilmu Pengetahuan dan Teknologi Kelautan* (2020). http://doi.org/10.14710/KAPAL.V17I2.29448
[27] Madrohim and Lukman Yudho Prakoso, "The Total War Strategy Through the Improvement of the Role of National Shipyard in Supporting Main Weapon System of Indonesian Navy," *The Influence of Sea Power upon History, 1660–1783*, Jan. 2021. http://doi.org/10.1017/CBO9780511783289

[28] Praharsi, Yugowati, Mohammad Abu Jami'in, Gaguk Suhardjito, and Hui-Ming Wee. "Barriers and Enablers for developing sustainable supply chain at traditional shipyards in East Java, Indonesia." In *Proceedings of the International Conference on Industrial Engineering and Operations Management*. 2020.
[29] Robert. E. Cole, "From Continuous Improvement to Continuous Innovation," vol. 8, no. 4, pp. 7–21, Jan. 2018. http://doi.org/10.1080/10686967.2001.11918977
[30] Nascimento, Daniel Luiz de Mattos, Osvaldo Luiz Goncalvez Quelhas, Rodrigo Goyannes Gusmão Caiado, Guilherme Luz Tortorella, Jose Arturo Garza-Reyes, and Luis Rocha-Lona. "A lean six sigma framework for continuous and incremental improvement in the oil and gas sector." *International Journal of Lean Six Sigma* 11, no. 3 (2020): 577-595. http://doi.org/10.1108/IJLSS-02-2019-0011
[31] Gaus, Nurdiana. "Selecting research approaches and research designs: A reflective essay." *Qualitative Research Journal* 17, no. 2 (2017): 99-112. http://doi.org/10.1108/QRJ-07-2016-0041/FULL/XML.
[32] Faulkner, William, and Fazleena Badurdeen. "Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance." *Journal of cleaner production* 85 (2014): 8-18. http://doi.org/10.1016/J.JCLEPRO.2014.05.042
[33] "Jumlah Industri Jasa Menurut Jenis Industri di Kabupaten Aceh Barat - Tahun 2020 - Open Data Aceh Barat."
[34] Irawan, Aldi, and Eko Budi Leksono. "Analisis Beban Kerja pada Departemen Quality Control." *Jurnal INTECH Teknik Industri Universitas Serang Raya* 7, no. 1 (2021): 1-6. http://doi.org/10.30656/INTECH.V7I1.2537
[35] Calzavara, Martina, Alessandro Persona, Fabio Sgarbossa, and Valentina Visentin. "A model for rest allowance estimation to improve tasks assignment to operators." *International Journal of Production Research* 57, no. 3 (2019): 948-962. http://doi.org/10.1080/00207543.2018.1497816
[36] Ariani, Farida, and Khawarita Siregar. "Determination of Total Labor Plant 1 using Workload Analysis (WLA) Method In Compound Fertilizer's Industry." In *IOP Conference Series: Materials Science and Engineering*, vol. 648, no. 1, p. 012015. IOP Publishing, 2019. http://doi.org/10.1088/1757-899X/648/1/012015
[37] D. Trisusanto, C. Bariyah, and A. Kristanto, "Design of ergonomic work facilities on assembly station of Mozaic stone for increasing work productivity," *Asia-Pacific Journal of Science and Technology*, vol. 25, no. 01, 2020.
[38] Supriyadi, Supriyadi, Herlam Siregar, and Eko Hadi Sucipto. "Analysis of Work Load and Total Operator Needs on Final Inspection of Work Station." In *1st International Conference on Life, Innovation, Change and Knowledge (ICLICK 2018)*, pp. 297-301. Atlantis Press, 2019. http://doi.org/10.2991/ICLICK-18.2019.61
[39] Lubis, D. A., I. Pamungkas, and H. T. Irawan. "Lean Manufacturing Approach to Minimize Waste in The Process of Sorting Palm Oil Using the Value Stream Mapping Method." In *IOP Conference Series: Materials Science and Engineering*, vol. 1003, no. 1, p. 012028. IOP Publishing, 2020. http://doi.org/10.1088/1757-899X/1003/1/012028
[40] Reda, Hiluf, and Akshay Dvivedi. "Application of value stream mapping (VSM) in low-level technology organizations: a case study." *International Journal of Productivity and Performance Management* 71, no. 6 (2022): 2393-2409. http://doi.org/10.1108/IJPPM-03-2021-0118
[41] MIA, Abu SAYID, NUR-E. ALAM, and M. Kamal Uddin. "COURT SHOE PRODUCTION LINE: IMPROVEMENT OF PROCESS CYCLE EFFICIENCY BY USING LEAN TOOLS." *leather & footwear journal/revista de pielarie incaltaminte* 17, no. 3 (2017). http://doi.org/10.24264/lfj.17.3.3
[42] KARABAY, Gülseren, and Duygu Selen KANSUL. "Increasing the process cycle efficiency of a men trousers assembly line." *Textile and Apparel* 29, no. 3 (2019): 253-261. http://doi.org/10.32710/TEKSTILVEKONFEKSIYON.498921
[43] Pittenger, Dominique M. "Evaluating sustainability of selected airport pavement treatments with life-cycle cost, raw material consumption, and Greenroads standards." *Transportation research record* 2206, no. 1 (2011): 61-68. http://doi.org/10.3141/2206-08
[44] Schoer, Karl, Jan Weinzettel, Jan Kovanda, Jürgen Giegrich, and Christoph Lauwigi. "Raw material consumption of the European Union–concept, calculation method, and results." *Environmental science & technology* 46, no. 16 (2012): 8903-8909. http://doi.org/10.1021/ES300434C/SUPPL_FILE/ES300434C_SI_002.ZIP
[45] Breliastiti, Ririn. "Penerapan standar GRI sebagai panduan penyusunan laporan keberlanjutan tahun 2020 perusahaan sektor barang konsumen primer dan non-primer di bursa efek Indonesia." *EKOBISMAN: JURNAL EKONOMI BISNIS MANAJEMEN* 6, no. 2 (2021): 138-156.
[46] ILO, *Safety and Health at Work: A Vision for Sustainable Prevention*, vol. XX. 2014.