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Research Article

Continuous Improvement Strategy in Traditional Shipyard Industry: A Holistic Approach towards Sustainability

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Abstract

The sustainability of the Traditional Shipyard Industry relies heavily on continuous improvement is to the production process, with the aim of optimizing it by reducing waste. To address this need, this study proposes the use of a Value Stream Mapping tool integrated with Sustainability Indicators to suggest ideas for continuous improvement in the Traditional Shipyard Industry. The main contribution of this research is the development of a concept that enables the assessment of measurable environmental, economic, and social systems in the shipbuilding process in traditional shipyards, allowing for continuous monitoring of changes in the shipbuilding system. The research method included a literature review, direct observation through fieldwork, and discussions with owners, management, employees, and operators on ship production in several Traditional Shipyards in Aceh. The findings suggest that the proposed concept can provide direction for improvement, leading to continuous enhancement in ship production in Traditional Shipyards. This research provides valuable insights for industry practitioners and policymakers on how to achieve sustainability through continuous improvement in traditional shipbuilding.

Keywords: Continuous Improvement; Sustainability Indicators; Value Stream Mapping; Traditional Shipyard

1. Introduction

The success of a company in winning the competition is one of the important factors that must be carried out by the company through a superior, competitive, and sustainable production performance improvement (PI) strategy. This is because continuous improvement (CI) is an integrated strategy in the manufacturing industry in product development activities, production processes, and services provided to customers, and can be evaluated continuously when improving company performance (Mrugalska & Wyrwicka, 2017, Zhou et al., 2018). Frequently managers in making improvements to the manufacturing industry only rely on examining and detecting problems that occur in the production process, but CI is an activity that must be carried out for each sector and field within the organization which is an approach that refers to the unique circumstances of a problem. They occur in the production line and are carried out in an integrated manner against several improvement standards 5S (McLean et al., 2015, Pambreni et al., 2019, Randhawa and Ahuja, 2017).

This unique problem situation is experienced by the TSI because this industry has production characteristics that are different from other industries, such as labor recruitment methods, simple production equipment, and generally wood materials, and the ship design is determined by the shipyard owner (Cil et al., 2021, DiBarra, 2002, Rizwan et al., 2021). In addition, shipbuilding is based on make-to-order (Tan et al., 2020). Meanwhile, all designs for these ship orders are determined entirely by the Traditional Shipyard Industry (TSI), with the main source of raw material being wood, non-standard working methods, and the use of traditional techniques which has an impact on the dominant use of human power in the production process (Praharsi et al., 2019, Rizwan et al., 2021). This results in waste in the manufacturing process, which reduces the performance of the shipbuilding process in the TSI (Fitriadi and Ayob, 2022, Sulaiman et al., 2017, Xue et al., 2020).

Previous research provides valuable insights into CI, but there are still gaps in its application across all organizational sectors. This study aims to develop a new method in the TSI to implement CI holistically and examine its impact on overall company performance. Likewise, there are gaps in the development of strategies to improve production performance and reduce waste in the TSI. Therefore, further research is needed to develop appropriate and effective strategies to ensure the sustainability of the industry. This study aims to address this gap by developing an integrated strategy that covers production, management, and environmental aspects.

Despite the extensive research conducted on this topic, limited attention has been given to developing PI strategies and reducing waste in the TSI. Particularly, the application of integrated approaches that encompass production, management, and environmental aspects remains scarce. Therefore, further research is crucial in developing appropriate and effective strategies to enhance production performance and ensure the sustainability of the TSI. In light of this gap, this research aims to develop such strategies

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It is uncommon to come across research studies aimed at the performance of production processes in the modern and TSI that is oriented toward sustainability. This increase is based on organizational development oriented towards identifying new realities that focus on CI, which is an effective and efficient way so that companies are superior and competitive (Souza and Alves, 2018). A company's competitive advantage can be achieved through innovative actions and new ways of implementing technology that focuses on cost advantages and differentiation advantages because these two things can be easily adapted in sustainable development (Amran et al., 2019). Improvements in the performance of production processes in shipyards that have been carried out so far are still technically oriented production processes. Several of the following research studies have made improvements to shipyard performance, both conceptual improvement proposals, simulations, and direct maintenance in shipyards. Since 2002 research on shipyard improvement proposals has been carried out and continues to be improved. In this paper, DiBarra (2002) provides suggestions for improving shipyards through the 5S program to provide changes in the work culture in shipyards. Other studies have also carried out performance improvements in shipyards that prioritize the logistics process between the fabrication panels and the assembly stage through software simulation with the results being able to formulate an improvement implementation framework (Dev and Fung, 2019). The use of the software is needed to assist companies in managing facilities effectively so that they can reduce company operational costs which have an impact on improving company performance (Wang et al., 2020). Other writings explain that shipyard repairs can be carried out by developing technology transfer concepts and models that can reduce investment losses and increase company productivity (Firmansyah and Djafar, 2017). Improving the efficiency of the Madura UKM shipyard's production process focuses on reducing activities that do not provide added value, this research was conducted by integrating the Simulation method, Value Stream Analysis Tool (VALSAT), Response Surface Methodology (RSM), and Analytical Hierarchy Analysis (AHP) (Estiasih et al., 2017). In addition, Manea & Manea, (2019), in their paper have made PI in shipyards, but improvements are only focused on improving organizational performance based on internal identification and assessment of organizational activities that have risky action plans. Meanwhile, Baso et al., (2020) presented an improved shipyard performance through increased competitiveness based on internal and external factors. This paper does not discuss the details of sustainability-oriented PI. Internal factors include organizational management, costs, production and maintenance technology used, and product quality. The discussion of the workforce, customers, and suppliers has not been explained in detail. While external factors only highlight partners, government policies, employee development, and shipyard clusters. Discussion of the technological environment, socio-cultural and demographic factors have not been described in detail. The paper by Madrohim and Prakoso, (2021) mentions increasing the capability of the national shipbuilding industry based on capacity-building factors and policy implementation. This paper is based on the view to realize Indonesia's defense sovereignty.

Given the universality of the desire to improve a company’s performance, many different concepts and methods have been developed around the idea of CI. No single method is guaranteed to provide the best solution in every case and application, each application of concepts and methods provides different strengths. The selection of concepts and methods of implementing the CI approach in solving problems in corporate organizations is important. The following papers will explain sustainability-oriented improvements. According to Praharsi et al., (2020) in their paper, it is explained that sustainable supply chain improvements in traditional shipyards using the AHP method can provide environmentally friendly shipbuilding proposals that can increase sales volume and business excellence.

CI has many benefits for business continuity, this can be done by focusing on alternative and creative ways based on quality improvement through continuous innovation (Cole, 2018). Nascimento et al., (2020) succeeded in building a conceptual framework for solving problems in the oil and gas sector through continuous and gradual improvements by integrating lean production and six sigma to be able to provide a systematic and comprehensive approach. According to Vaezi, (2021), three indicators of sustainability consisting of social, economic, and environmental are able to identify problem criteria so that they can provide solutions for improving performance. Meanwhile, according to Azadnia and Ghadimi, (2018), the paradigm of sustainability has influenced manufacturing companies in the supply chain network.

Although the CI approach has significant benefits in enhancing company performance, research indicates that its application still has some weaknesses. While certain studies have demonstrated that selecting appropriate concepts and methods can result in benefits such as increased sales volume and a competitive edge, others have emphasized the need to integrate them into a systematic and comprehensive approach to effectively address organizational problems. Furthermore, incorporating sustainability aspects such as social, economic, and environmental factors can assist in identifying problems and delivering sustainable solutions. As a result, this study aims to integrate CI into the TSI's revitalization process using Sustainability Indicators (SI) and Value Stream Mapping (VSM). By using a systematic and comprehensive approach, the study seeks to achieve sustainable and long-lasting improvements in the TSI.

The integration of the VSM method with SI is crucial in this research. SI cannot effectively provide the intended benefits if they are not integrated with other methods. This is supported by previous studies, such as those by (Engert et al., 2016; Wijethilake & Ekanayake, 2018), which suggest that integrating SI into an organization's Performance Management System (PMS) can assist management in making decisions and having a real impact on managerial practices. Conversely, the lack of integration of SI, as reported by Baird et al., (2023), can lead to a disconnect between external sustainability disclosures and internal sustainability actions, which has been identified as a problem in sustainability reports (Zharfpeykan, 2021). Additionally, studies by Jollands et al., (2018), de Villiers et al., (2016), Kerr et al., (2015), and others have emphasized the importance of integrating sustainability practices, such as PMS and balanced scorecard (BSC), to provide more substantial value and contribute positively to company performance while promoting social, economic, and environmental sustainability outcomes (Hristov et al., 2019; Morioka & Carvalho, 2016). Therefore, this research aims to integrate the VSM method with SI to achieve a comprehensive and systematic approach to revitalizing the TSI, leading to sustainable improvements.

VSM has been widely used in shipbuilding studies, as demonstrated by several studies. Storch & Williamson, (2003), stated that VSM has the potential to significantly improve ship design processes by identifying process steps in-depth and aligning them with the company's goals and strategies. Kolich et al., (2014) applied VSM to the steel pre-assembly process in shipbuilding and found that the study can formulate a better value stream map in the future, leading to a significant reduction in working hours and duration time. Meanwhile, Kolich et al., (2014) combined VSM with grouping techniques for assembly panel types and achieved a reduction in assembly time and elimination of excessive work processes, leading to increased availability value. Sharma & Gandhi, (2017) proposed applying lean principles and practices to the shipbuilding industry culture by choosing VSM as a tool, which can gradually reduce production time and increase productivity. Estiasih et al., (2017), used VSM to map individual products, product groups, and product lines throughout the ship production process at UKM Madura Shipyard, finding that activities such as hull making, machine equipment, and electrical equipment were still low in the process, requiring improvement. Tebiary et al., (2017) stated that VSM has successfully performed the identification of waste and visualized the production process flow activities in the shipbuilding process, enhancing the effectiveness of the production process. Fatouh et al., (2020) found that VSM could develop a future state map by eliminating time wastage in the value stream flow network, which was useful in reducing losses in the production process in engineer to order Shipbuilding Industry in Norway. Lastly, Kunkera et al., (2022) showed that VSM could reduce losses in the process by reducing waiting time in internal and external communication, resulting in cost savings in ship sales and employee productivity growth, contributing to a smooth production process and substantial sales and revenue growth in the shipyard.

Given the importance of CI in improving the performance of the TSI, as well as the demands of the scientific community and practitioners, this paper aims to provide recommendations for CI in the TSI using a VSM tool that is integrated with SI consisting of environmental, economic, and social systems.

2. Methodology

Choosing the right research method is very important so that research findings can provide good scientific references and can be used in further research to advance theory and research (Gaus, 2017). A literature review was carried out through highly reputable journal articles on sites such as Google Scholar, ScienceDirect, IEEE Xplore, Emerald Insight, ResearchGate, Academia.edu, ProQuest, Taylor & Francis, and Elsevier. The keywords used during the search are CI, SI, VSM, lean manufacturing, sustainable manufacturing, and shipyard. Figure 1 illustrates the methodology used in this study.

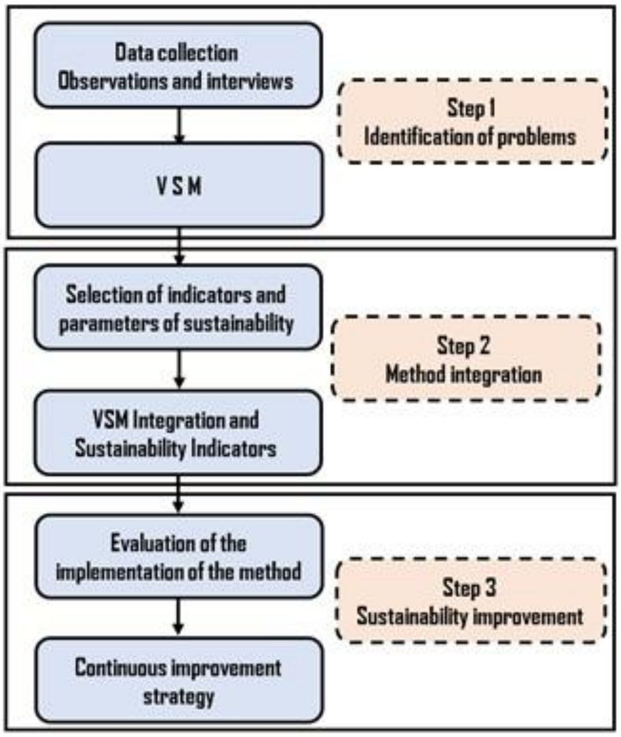

Fig .1. Research methodology

The research method in this work is carried out in several steps. The first step taken is to overcome the problems that occur in the production line by mapping the ship production process flow in the TSI using VSM. Step 2 selects parameters for SI which are then integrated with the mapping results in Step 1. Step 3 analyzes possible strategies recommended for CI in the TSI. VSM integration and SI are based on the model of Faulkner and Badurdeen (Faulkner and Badurdeen, 2014). To evaluate the application of the integrated VSM method with SI using environmental, economic, and social parameters, a case study was conducted on 5 shipyards out of 11 traditional shipyards in West Aceh District (Open Data Aceh Barat, 2020).

Step 1 begins with direct observation and interviews with traditional shipyard owners. The results of these interviews obtained operational conditions, costs incurred, and the selling price of ships in traditional shipyards, as shown in Tables 2 and 3. The ns on production lines in traditional shipyards obtained cycle times (*CT*) for each size of ship volume, as shown in Table 4. The next work in step 1 is to determine the standard time. Calculation of standard time (*ST*) can be done using equations (1) and (2) (Calzavara et al., 2019, Irawan and Leksono, 2021, Supriyadi et al., 2019, Trisusanto et al., 2020).

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

$$ST = NT\ x\ 100/(100 - All) \quad (2)$$

ST; is standard time, and *Rf*; is a rating factor, where the *Rf* value is obtained through direct observation of the TSI, The results of these observations are then adjusted to the values in Table *All* (Trisusanto et al., 2020). *CT*; is the cycle time of the shipbuilding process in a traditional shipyard. *All*; is a concession, where the value of *All* is obtained through direct observation of the traditional shipbuilding industry, then the results of these observations are adjusted to the values in Table *All* (Calzavara et al., 2019; Trisusanto et al., 2020).

The first step is to identify the problem to identify non-value-added (*NVA*) and value-added (*VA*) activities. *NVA* is obtained through value flow mapping using the VSM method to identify waste that occurs in shipyard production lines in the TSI. The mapping results obtained waste consisting of Transportation (*T*), Motion (*M*), Inspection (*I*), Waiting (*W*), and Storage (*S*), as in Table 6. Calculation of *NVA* and *VA* can be done using equations (3) and (4) (Fitriadi et al., 2020b, Reda and Dvivedi, 2022).

$$NVA = T + M + I + W + S \quad (3)$$

$$VA = CT - VA \quad (4)$$

The final work in step 1 is to determine the Process Cycle Efficiency (*PCE*) value. *PCE* calculations are performed using equation (5) (Abu and Mia, 2017, Fitriadi et al., 2020a, Kansul and Karabay, 2019).

$$PCE = VA/CT\ x\ 100\% \quad (5)$$

Step 2 in this research method is selecting SI that is appropriate to the case study. The selected SI are environmental, economic, and social. The next three indicators are the selection of the right parameters to be able to integrate VSM and SI. The selected SI parameters are shown in Table 1. Step 3 is the last in this research method, this step evaluates the integration results of VSM and SI. The results of this evaluation can then be proposed possible strategies to be applied to the TSI, to provide recommendations for CI.

Table 1
SI used in the TSI

Indicator	Parameter	Description
Environment	Raw material consumption	Use of raw materials or those consumed during a production cycle or a certain period and those that are disposed of as scrap.
	Energy consumption	Energy is used or consumed during a certain production cycle or period.
Economic	*CT*	The time needed to carry out work activities in each work element to produce 1 unit of ship product.
	Takt time	The amount of time needed to produce one unit of a ship to meet customer demand.
	NVA	In the TSI, activities in the manufacturing process flow do not add value to the ships produced.
	VA	Activities in the production flow of the TSI have added value to the ships produced.
	PCE	Comparison between VA and total lead time.
	Labor cost	The total costs incurred by the traditional shipbuilding industry to pay workers' wages during the production process.
	Material cost	All costs incurred during the production of the ship include the cost of material prices, transportation costs, and storage.
Social	Work environment risk	Health risks or work accidents that occur in the work environment.
	Attendance and absence days	The presence and absence of workers during the production process in traditional shipyards take place.
	Salary level	The level of wages paid to workers in the traditional shipbuilding industry.
	Diversity ratio	The degree of employee difference measure was found to be a minority of the total organizational strength.

In order to further advance the integration of SI and VSM in TSI, it is essential to merge the calculations of the three SIs that were applied to the selected parameters within each SI. The calculation process can be facilitated through equations (6) to (16).

$$RMR = \sum \frac{RMC}{PSP} \quad (6)$$

$$ECR = \sum \frac{ECC}{PSP} \quad (7)$$

$$EvIL = \sum \frac{RMR + ECR}{2} \quad (8)$$

$$OC = CT \, x \, (RMC + ECC + LC) \quad (9)$$

$$EC = \frac{OC}{OEE} \quad (10)$$

$$Takt\ Cost = \frac{\sum OC}{OEE\ ref} \quad (11)$$

$$EcIL = \frac{Takt\ Cost}{EC} \quad (12)$$

$$AbsR = \frac{NHA}{NHW} \quad (13)$$

$$AR = \frac{NoA}{NoE} \quad (14)$$

$$WADR = \frac{\boldsymbol{P_{DA}}}{\boldsymbol{TP_{TSI}}} \quad (15)$$

$$SIL = \frac{AbsR + AR + NPR}{3} \quad (16)$$

This equation set represents a collection of mathematical formulas used to calculate various indicators of company performance in TSI. The calculations begin with environmental indicators, from Equation (6) to Equation (8), which are explained below. Equation (6) calculates the raw material rate (*RMR*), which is the ratio between total raw material cost (*RMC*) and the product selling price (*PSP*). Equation (7) calculates energy consumption rate (*ECR*), which is the ratio between total energy cost and the product selling price. Equation (8) calculates the Environmental Indicator Level (*EvIL*), which is the average of *RMR* and *ECR*.

Economic indicators are calculated using equations (9) to (12), which are explained below. Equation (9) calculates Operating Cost (*OC*), the cost of production operations that includes *RMC*), *ECC*, and labor costs (*LC*). Equation (10) calculates Cost Efficiency (*EC*), which is the ratio of *OC* to overall tool effectiveness (*OEE*). Equation (11) calculates Takt Cost, the production cost per unit of standard time, which is the ratio of *OC* to OEE based on the reference (OEE_{Ref}). Equation (12) calculates the Economic Indicator Level (*EcIL*), the ratio of Takt Cost to *EC*.

Social indicators are calculated using equations (13) to (16), which are explained below. Equation (13) calculates the absent rate (*AbsR*), which is the ratio of employee absences (*NHA*) to hours worked (*NHW*). Equation (14) calculates the Accident rate (*AR*), which is the ratio of accidents (*NoA*) to employees working (NoW). Equation (15) calculates the West Aceh District Rate (*WADR*), which is the ratio of West Aceh District products (*WADP*) to the total product produced in TSI (TP_{TSI}). Equation (16) calculates Social Indicator Level (*SIL*), the average of AbsR, AR, and NPR. By using these equations, company performance can be evaluated and improved by implementing CI strategies.

3. Results

The research results consist of four parts, namely; operational conditions of the traditional shipbuilding industry, identification of problems with VSM, VSM integration, and SI, and the last part a CI strategy. Case studies were conducted at 5 traditional shipyards for each vessel volume size consisting of 3, 4, 8, 12, 15, and 20 GT.

3.1. TSI operational conditions

The ship production process in traditional shipyards consists of 6 working days per week and 8 hours per day. Table 2 shows the operational conditions in traditional shipyards obtained through observation and interviews in 5 TSI for each ship volume size consisting of 3, 4, 8, 12, 15, and 20 GT. Takt time in Table 2 is calculated based on the available time multiplied by the total customer order time (demand per unit) for each size of ship volume. While Table 3 shows the relationship between ship volume size and costs incurred which consist of raw material and component costs, energy consumption costs, labor costs, and the selling price of ships. This data was obtained through direct interviews with 5 shipyard owners. Table 3 contains the results of average calculations in the TSI, which serves 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's 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

Table 2 presents the operational conditions of the TSI, encompassing several key variables. Firstly, Ship size (measured in gross tonnage or GT) denotes the weight of the vessel. Secondly, Request per unit (day) refers to the demand for shipping services required per unit of ship in a day. Thirdly, the time available (hours) indicates the duration available in a day to execute delivery operations. Fourthly, the number of orders (units) signifies the count of orders to be fulfilled in a day. Fifthly, the total workforce (people) refers to the number of workers available to carry out delivery operations. Lastly, Takt time (hours/unit) denotes the time required to produce or complete one unit of product or service.

The data in Table 2 reveals that an increase in Ship size (GT) corresponds with a higher demand per unit (day). The duration available for delivery operations remains constant at 8 hours daily. While the count of orders (units) to be fulfilled decreases as the ship size increases, the demand per unit (day) required also escalates. Furthermore, the total available workforce increases alongside the ship size, yet the takt time (hours/unit) increases with the decrease in the count of orders (units) to be fulfilled.

Table 3 showcases the TSI's cost components and selling prices for ships of various sizes. The data demonstrates that as the ship size increases, so do the associated expenses for raw materials, energy consumption, and labor. While the selling price rises along with the ship's size, the rate of increase is not proportional to the size of the ship. Notably, the selling price of a 15 GT vessel is only 33.33% higher than that of an 8 GT vessel, even though the latter is twice the size of the former.

3.2. Identification of problems with VSM

CI in the TSI through VSM that is integrated with SI begins with problem identification using the VSM tool. Problem identification is carried out in four stages, namely; the first stage measures *CT*, the second stage determines the standard time, the third stage is Process Activity Mapping (PAM), and the final stage is to determine the current *PCE* condition.

3.2.1. Measurement of CT

Table 4 below is the *CT* for each work activity for each size of ship volume. This data was obtained through direct observation in the TSI by recording the time of each work activity carried out in the shipbuilding process in the TSI. Observation results obtained 17 work activities which then facilitate the process of calculating and writing work activities are and coded alphabetically. The alphabetical order of the codes in Table 4 shows the order of the shipbuilding process in the shipyard industry.

Table 4
Shipbuilding CT 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

Table 4 displays the *CT* for building TSI ships of varying sizes, presenting the hours required for each work activity identified by code. The data highlights that as ship size increases, most work activities require longer *CT*, with exceptions for plastic sheeting and painting. For instance, constructing the keel of a 20 GT ship takes three times longer than for a 3 GT ship. Additionally, the total *CT* to build a ship increases with its size, with a 20 GT ship requiring four times longer than a 3 GT ship

3.2.2. Determination ST

Based on the data in Table 4, it can be determined the standard shipbuilding time in the TSI for each ship volume size using equations 1 and 2, table 5 displays the calculation results. Then the calculation results can be seen as follows.

Table 5
Standard time in shipbuilding 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

Table 5 displays the *ST* data of shipbuilding at TSI, demonstrating an increasing trend as the ship size grows. The *ST* is a function of the *CT*, worker efficiency (RF and *ALL*), and *NT*, which refers to non-productive time. The data reveals that larger vessels require more *ST* to complete, with a 20 GT ship needing nearly five times the ST of a 3 GT ship. Efficient workers and longer workdays decrease ST by reducing *NT*. Additionally, *RF* and *ALL* are crucial factors in determining *ST*.

3.2.3. Process activity mapping (PAM)

PAM is to identify the existence of *NVA* activities through direct observation in the TSI where this tool is part of the VSM. Based on these data, waste can be identified in the TSI. Table 6 shows the relationship between ship products based on ship volume size and *NVA* time identification data consisting of Transportation (*T*), Movement (*M*), Inspection (*I*), Waiting (*W*), and Storage (*S*). Data was obtained based on direct observation in the TSI. The *NVA* and *VA* values are calculated based on equations 3 and 4. Then the calculation results can be seen as follows.

Table 6
NVA identification results on 3 GT ship production volume in the 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

The *NVA* and *VA* values for other ship sizes can be calculated using the results shown in Table 6. The results as in Table 6 are then recapitulated into overall identification results for all types of ship volumes as shown in Table 7.

The *NVA* identification results for 3 GT vessel production at TSI are presented in Table 6. The data shows that the total *NVA* time for production is 44.98 hours, which accounts for 16.4% of the total production time. Work activities F, G, and O have the highest *NVA* times, with 3.02, 3.10, and 2.75 hours, respectively. Meanwhile, work activity P has the highest *VA* time of 4.86 hours. These findings suggest that reducing *NVA* time in activities F, G, and O could significantly enhance production efficiency. Similarly, optimizing *VA* time in activity P could also contribute to boosting production efficiency.

Table 7
NVA identification results in ship production in the 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

Table 7 presents the findings of *NVA* identification on ship production conducted at TSI. The results indicate that the *CT* and *NVA* time increase with the size of the ship. Nonetheless, the percentage of *NVA* time to total production time decreases as the ship size grows larger, which implies that there are potential economies of scale in ship manufacturing. Notably, Waiting (W) and Processing (S) activities are the primary sources of *NVA* time across all ship sizes, suggesting that reducing waiting and processing times should be prioritized to improve production efficiency. In summary, Table 7 offers valuable insights into ship production performance at TSI and highlights opportunities to enhance efficiency and reduce *NVA* time.

3.2.4. *PCE's current state*

Equation 5 can be used to calculate the current condition *PCE* value for each vessel volume size based on the *VA* calculation results in Table 7, the calculation results are shown in Table 8. Then the calculation results can be seen as follows.

Table 8
PCE of current conditions

Ship size (GT)	*CT* (hours)	*VA* (hours)	*PEC* (%)
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

Table 8 presents the interplay of *CT*, *VA*, and *PCE* with respect to ship size measured in GT. The data indicates that as ship size increases, so do *CT* and *VA*, albeit with a marginal decrease in *PCE* for larger ships. For instance, a 3 GT vessel has a *CT* of 319.2 hours, *VA* of 273.7 hours, and *PCE* of 85.72%, whereas a 20 GT vessel has a *CT* of 1438.5 hours, *VA* of 1248.3 hours, and *PCE* of 86.77%. These findings underscore the crucial correlation between ship sizes and performance metrics, such as *CT*, *VA*, and *PCE*, offering valuable insights for shipbuilders and designers seeking to enhance production efficiency in shipbuilding.

3.3. *VSM Integration and SI*

The unification stage of VSM and SI is carried out by linking the findings of problem identification using VSM with the results of observations and interviews using SI referring to Table 1. This stage is described based on SI which consists of 3 parts, namely environmental indicators, economic indicators, and social indicators.

3.3.1. Environment indicators

The parameters used for environmental indicators in ship production in the TSI are raw material consumption and energy consumption. Based on observations and interviews, it is known that the main material for shipbuilding in the TSI is wood, and sources of wood raw materials are diminishing and difficult to obtain [6]. This shows that the sustainability of the TSI when viewed from the source of raw materials is not yet sustainable. But when viewed from the consumption of raw materials is very effective and efficient. According to Table 3, the comparison and percentage of costs incurred for raw materials when compared to shipping products is 1:2.85 and 35.63%, respectively. The ratio and percentage comparison of raw material consumption to ship products is still low because it has a percentage value that is still below 50% (Pittenger, 2011, Schoer et al., 2012). This shows that the TSI has utilized raw materials optimally, this is because the scrap that occurs in the production process is still low. Therefore, the TSI shows that it still maintains terrestrial ecosystems through optimal utilization of raw material sources from plantations (Breliastiti, 2016). Therefore, based on the parameters of raw material consumption, the TSI meets SI.

The energy consumption parameter in environmental indicators for the ship production process in the TSI based on observation and interview data shows that the energy consumption value used is still low. This can happen because the percentage of costs incurred for energy use when compared to the value of the product is only 1.2%. This low energy consumption is because it is only intended for the 6 engines used in ship production in traditional shipyards. This situation shows that in the TSI when viewed from environmental indicators, Energy consumption parameters are considered sustainable.

3.3.2. Economic indicators

The parameters used to measure the level of sustainability of the TSI based on economic indicators are *CT*, Takt time, *NVA*, *VA*, *PCE*, labor costs, and material costs. According to Tables 2 and 4, the shipbuilding process in the TSI is capable of meeting customer demands. This can be seen from the comparison between *CT* and takt time (*CT* A-Q ≤ Takt Time). Therefore, based on the *CT* and takt time parameters, the TSI meets the SI.

Parameters *NVA*, *VA*, and *PCE* in economic indicators for the ship production process in the TSI are interrelated parameters. According to Table 7, ship production in the TSI still includes non-value-added activities. This can be demonstrated by the time value of *NVA* in the production process. The lowest *NVA* time value was found in the production of 3 GT vessels which was 45.6 hours and the highest *NVA* was found in the production of 20 GT vessels amounting to 190.3 hours. The increase in *NVA* value in ship production is directly proportional to the increase in ship volume size. The comparison of the average percentage of *NVA* and *VA* in ship production in the TSI is 16.6%. The *PCE* parameters shown in Table 8 visualize that the ship production process in the TSI is inefficient. Therefore, based on the *NVA*, *VA*, and *PCE* parameters, the TSI has not met SI so it requires improvement.

Labor and material cost parameters in traditional shipyard economic indicators meet SI. This is because the costs incurred for labor and materials do not have a waste value, with a comparison of labor costs of 14.3% and material costs of 35.6% of the value of shipped products.

3.3.3. Social indicators

The parameters used to measure the level of sustainability of the TSI based on social indicators are work environment risk, days of attendance and absence, salary level, and diversity ratio. A good work environment is a work environment that has a small risk to the level of health and safety of employees. Thus, to improve the health and safety of workers and thereby increase worker productivity, good working conditions and the environment must be considered (ILO, 2014).

Based on the findings of interviews in the TSI, there has never been a work accident that could cause workers to get sick and die, even though the type of equipment and work methods used in the industry use more human power. This is because the workers who make ships are skilled workers based on experience passed down from generation to generation. Therefore, based on the parameters of work environment risk, the TSI meets SI.

In the TSI, the parameters of days of absence and absence in the ship production process meet SI. This happens because in every production process that takes place, all workers are present, and no workers are absent, because the work methods carried out by the owner and workers are wholesale for each product. Likewise, the salary level parameter fulfills the SI, because there are no workers who experience dissatisfaction with the salary earned, this is because the payroll method uses the contract per unit ship method. According to the research findings for the diversity ratio parameter, all workers in the TSI are men who are hired based on kinship, so the workforce tends to be homogeneous and have almost the same characteristics, there are no significant differences that disrupt the corporate organization.

3.3.4. Indicator level in TSI

Utilizing the VSM identification data presented in Tables 2 and 3, the sustainability indicator level can be calculated through a staged process outlined in equations (6) to (16). The resultant values are displayed in Table 9, and offer an insightful performance evaluation of each individual indicator, providing a comprehensive sustainability assessment.

Table 9
Indicator level in TSI

Indicator	Environment			Economic			Social				
Parameter	RMR	ECR	EvIL	OC	EC	Takt Cost	EcIL	AbsR	AR	NPR	SIL
Parameter values	0,356	0,012	18,42	3,03E+11	4,15E+11	5,69E+11	85,88	0,563	0,0	2,20	92,08

Presenting a tabular representation of the TSI's indicator levels, Table 9 displays three primary indicators: environmental, economic, and social, accompanied by their respective sub-indicators and parameter values. Notably, RMR reflects a parameter value of 0.356 for the Environment indicator, whereas EvIL reports a value of 18.42 for the same category. Similarly, OC and SIL denote the parameter values of 3.03E+11 and 92.08, respectively, for the Economic and Social indicators. By employing the values tabulated, the TSI can be calculated to obtain a comprehensive assessment of a system or process's sustainability performance.

3.4. VSM Integration and SI

Based on the implementation of VSM integration and SI in the TSI, found several parameters in the SI which is the main goal of CI can make the TSI competitive, superior, remain competitive, and sustainable. The parameters in the SI that are the main focus of CI are parameters that do not meet the SI. Overall CI strategy recommendations for each indicator and parameter are shown in Table 10.

Table 10
CI strategy recommendations

Indicator	Parameter	CI strategy recommendations
Environment	Raw material consumption	- Increasing the workforce's ability and skills through training to reduce the risk of failure in raw material processing in the TSI, which has an impact on the low level of scrap produced. - Technology updates on the use of cutting tools and other processing tools so that the risk of failure in processing raw materials in the TSI has an impact on the low scrap produced. - Provide a special place to store waste or scrap, so that around the TSI it is not dirty and it is more comfortable to do work.
	Energy consumption	- Carry out technological updates on the use of process equipment, so that the level of energy consumption, in this case, the amount of fuel, is lower. - Carry out routine maintenance and schedule periodic maintenance of the process equipment used, so that the performance of the equipment is better which will have an impact on energy consumption.
Economic	*CT* dan Takt time	- Rearranging the production line and work facility layout. - Carry out the application of 5S work principles thoroughly and systematically.
	NVA, *VA* dan *PCE*	- Reorganize storage of tools and equipment. - Reset raw material storage. - Updating technology using process tools so that the use of human power is not dominant. - Scheduling the use and purchase of raw materials thereby reducing waiting times.
	Labor cost	- Rescheduling workers' working hours and changing the method of payment of wages according to working hours or working days.
	Material cost	- Increasing the workforce's ability and skills through training in the hopes of lowering the likelihood of failure in raw material processing in the TSI, which has an impact on optimizing raw material use. - Updating the technology for using cutting tools and other production tools to reduce the risk of failure in raw material processing in the TSI has an impact on optimizing raw material use. - Recycle waste and scrap to increase its resale value.
Social	Work environment risk	- Conduct socialization on the use of personal protective equipment (PPE). - Increasing participation and monitoring of work activities by leaders or owners of the TSI. - Implement occupational health and safety management as a preventive planning and control system.
	Attendance and absence days	Give rewards to workers who have high discipline towards attendance.

Salary level	Changing the method of payment of wages based on working hours or working days.
Diversity ratio	- Improve communication between workers in the work environment. - Organizing routine recreational activities for colleagues in the form of family gatherings. - Improve the compensation and reward system. - Prepare facilities that can support workers' hobbies.

The recommendations in Table 10 for CI strategies are expected to reduce waste in ship production in the TSI. Because the results of integrating these parameters do not meet the SI, the recommendations on the economic indicators of the *NVA*, *VA*, and *PEC* parameters are the main focus. The TSI's sustainability is highly dependent on how the industry implements CI recommendations. Therefore, these improvement recommendations are expected to provide direction for CI of ship production in the TSI to be able to win the competition with competitive and sustainable advantages.

The study identified raw material and energy consumption as the selected environmental indicators for TSI's CI evaluation. To evaluate their impact on ship production performance at TSI, a simulation can be conducted. Likewise, CT, Takt time, NVA, VA, PCE, labor costs, and material costs were identified as the selected economic indicators for TSI's CI evaluation. A simulation can also be carried out to determine the effect of a decrease or increase in labor costs and material costs on ship production performance at TSI. The study also identified work environment risk, attendance and absence days, salary level, and diversity ratio as social indicators for TSI's CI evaluation. A simulation can be conducted to assess the impact of a decrease or increase in these social parameters on ship production performance at TSI. These indicators can be used to formulate more accurate and targeted CI strategy recommendations for TSI to improve its ship production performance and gain a competitive advantage with sustainability.

4. Conclusion

CI of the TSI through VSM integration and SI can be evaluated through the mapping of production lines. According to the evaluation results, the performance of ship production in the TSI is not optimal. This can be shown by the average *PEC* of 85.78%. *PEC* for each ship size is 3 GT = 85.72%, 4 GT = 83.98%, 8 GT = 84.9%, 12 GT = 86.04%, 15 GT = 87.25% and 20 GT = 86.77%. This demonstrates that the cycle time and standard time in the TSI's ship production process have not shown the actual cycle time and standard time, but this time still includes *NVA* time which consists of transportation time, motion, inspection, waiting time, and storage time. The cycle times for each ship size are 3 GT = 319.2 hours, 4 GT = 478.8 hours, 8 GT = 719.1 hours, 12 GT = 958.5 hours, 15 GT = 1198.1 hours, and 20 GT = 1438 .5 hours. The standard time for each ship size is 3 GT = 406.4 hours, 4 GT = 676.3 hours, 8 GT = 787.4 hours, 12 GT = 1086.7 hours, 15 GT = 1220.3 hours, and 20 GT = 1660.5 hours. The *NVA* time values for each ship size are 3 GT = 45.6 hours, 4 GT = 76.7 hours, 8 GT = 108.6 hours, 12 GT = 133.8 hours, 15 GT = 152.8 hours, and 20 GT = 190.3 hours.

Based on these findings, the VSM integration and measurable SI consist of environmental, economic, and social systems. The selected parameters for environmental indicators are raw material consumption and energy consumption. The selected parameters for economic indicators are *CT*, Takt time *NVA*, *VA*, *PCE*, labor costs, and material costs. While the parameters for social are work environment risk, days of attendance and absence, salary level, and diversity ratio.

The results of this integration can provide recommendations for CI strategies. The recommendations that are main focus are the recommendations on the economic indicators of the *NVA*, *VA*, and *PEC* parameters because the results of the integration of these parameters do not meet the SI. The recommendations given are 1. Rearranging the storage of tools and equipment. 2. Reorganize raw material storage. 3. Updating technology using process tools so that the use of human power is not dominant. 4. Scheduling the use and purchase of raw materials thereby reducing waiting times. These improvement recommendations are expected to provide direction for a sustainable increase in ship production in the traditional shipping industry to be able to win the competition with competitive and sustainable advantages.

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