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# Supply chain performance for a traditional shipbuilding industry in Indonesia



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## Abstract

**Purpose** – Study in supply chain performance research on the shipbuilding industry is lacking. The purpose of this research is to study and provide guidelines to improve the performance of traditional shipbuilding supply chains in Indonesia.

**Design/methodology/approach** – The paper develops an empirical study gathered from a traditional shipbuilding industry, its suppliers, and customers. This study consists of three sections: the traditional shipbuilding industry, the suppliers, and the individual supplier scores. The internal and external performances in this study are measured using Supply Chain Operations Reference (SCOR) metrics. The SCOR model identifies five performance measurement attributes, including reliability, flexibility, responsiveness, cost and assets. Instead of using "responsiveness," this study applies the schedule performance index, and supplements "cost" with the cost performance index in order to accurately reflect the traditional shipbuilding supply chains processes.

**Findings** – By analyzing SCOR metrics in the traditional shipbuilding industry, it has been found that the ideal shipbuilding supply chain metrics are order fulfillment, flexibility, asset turnover and total supply chain costs. The lowest performance metric value in the traditional shipbuilding industry is the cost of goods. Some improvements are proposed to lower the high cost of ship building. An integrated economic ordering system in collaboration with all the suppliers is one of the most effective ways to reduce the cost of the traditional shipbuilding supply chains. The implementation of SCOR metrics enables management to identify the critical issues to improve.

**Research limitations/implications** – The study applies SCOR metrics to improve the traditional shipbuilding supply chains performance. The study is limited because the data collected are based on one shipbuilding industry only.

**Originality/value** – To the author's knowledge, this is the first empirical analysis on the implementation of SCOR metrics to the traditional shipbuilding industry. The analysis to improve the traditional shipbuilding supply chains performance can provide managerial insights to other industries.

**Keywords** Traditional shipbuilding, SCOR metrics, Supply chain performance, Indonesia

**Paper type** Research paper

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## 1. Introduction

The shipbuilding industries are clustered in several areas in Indonesia. The four major clusters are Surabaya, Lamongan, Tuban and Gresik. The Lamongan shipbuilding industry has produced over 10,000 traditional boats in various sizes of gross tonnage. Traditional shipbuilding industries are characteristically based on engineering to order. Although they have produced lots of boats, the performance of these traditional shipbuilding industries has not been studied in depth.

To be able to assess the success of supply chains, an adequate performance measurement system (PMS) must be developed (Aramyan *et al.*, 2007). The selection of supply chain measures is critical because managers have to evaluate the supply chain on various aspects as a whole entity rather than on an individual basis (Gopal and Thakkar, 2012). The literature discusses general shipbuilding industry performance is sparse. Panayides *et al.* (2018) presented key performance indicators (KPIs) for offshore logistics with a special emphasis on a harsh operational environment. Sanderson and Cox (2008) found that the design and build process used in the shipbuilding industry introduces radical unpredictability into the demand for functional components of naval vessels. Vlachakis *et al.* (2016) described the strategic co-operations between shipbuilding industry's suppliers for improving supply chain performance in terms of lead times and product quality. Mello *et al.* (2015) presented how coordination can improve delivery performance in engineering to order supply chains. The goal of this study is to address research gaps in shipbuilding industry performance measurement, which will allow shipbuilding industry companies to find new ways to enhance productivity.

Several literature examples show how supply chain performance is measured. Rotaru *et al.* (2014) identified how supply chain risk management has been incorporated into Supply Chain Operations Reference (SCOR). Stewart (1997) presented that the SCOR is the first cross-industry framework for evaluating and improving enterprise-wide supply chain performance management. Lu *et al.* (2016) applied the SCOR framework to the context of humanitarian supply chains. Lockamy and McCormack (2004) investigated the relationship between supply chain management planning practices and supply chain performance based on the SCOR model version 4.0. Huan *et al.* (2004) analyzed the strength and weakness of SCOR model to assist the managers for strategic decision-making. The implementation of SCOR in the traditional shipbuilding industry will add theoretical and practical implications of supply chain management, particularly projects based on engineering to order.

The rest of the paper is organized as follows. Section 2 presents a literature review. Section 3 discusses the research methodology. Results and discussions are described in Section 4. Finally, Section 5 presents the conclusions, limitations, and future research directions derived from this paper.

## 2. Literature review

### *2.1 Supply chain and supply chain performance*

Pujawan (2005) said the supply chain is a network of some companies or organizations that work together to create and distribute a product to the consumer or end user. The company usually includes suppliers, manufacturers, distributors, stores, or retail and supporting companies such as logistics service company. A supply chain is a network of partners who collectively convert a basic commodity (upstream) into a finished product (downstream) that is valued by end customers, and who manage returns at each stage.

In a supply chain, three kinds of streams must usually be managed. First is the flow of goods from upstream to downstream. Examples are raw materials delivered from the supplier to the factory. After the finished products are produced, they are sent to distributors and retailers or retail, and then to the end user. Second is the flow of money from downstream to upstream. Third is the flow of information that could happen from upstream to downstream, or vice versa (Pujawan and Mahendrawati, 2017).

Meanwhile, according to Van der Vorst (2004), supply chain management is the process of planning, coordinating and controlling activities in the supply chain to provide the cost-effective purchase of goods and services, while satisfying customer requirements. The Council of Supply Chain Management Professionals also states that Supply Chain Management (SCM) involves all the tasks and activities performed by an organization or individual in the planning, procurement, conversion and logistics for goods and services. More importantly, supply chain also involves integration with channel partners, which are suppliers, intermediaries, third-party services providers and customers.

Anantan and Ellitan in Setiadi *et al.* (2018) explained supply chain management is a complex process used to manage and coordinate all the activities contained within the supply chain that can run efficiently and effectively in accordance with the function of supply chain management. Essentially, supply chain management has three main objectives: cost reduction, capital reduction and repair services. The purpose of supply chain management is to coordinate the activities in the supply chain to maximize profitable benefit and satisfy the end consumer (Heizer and Rander, 2014).

To improve a supply chain, it is essential to measure its performance effectively and efficiently (Sari *et al.*, 2017). For effective supply chain management, measurement systems capable of holistic evaluations of the performance are needed. PMSs are required to (1) monitor and control, (2) communicate the goals of the organization, (3) determine the position of an organization relative to competitors and its objectives and (4) determine the directions for competitive advantage improvement (Pujawan and Mahendrawati, 2017).

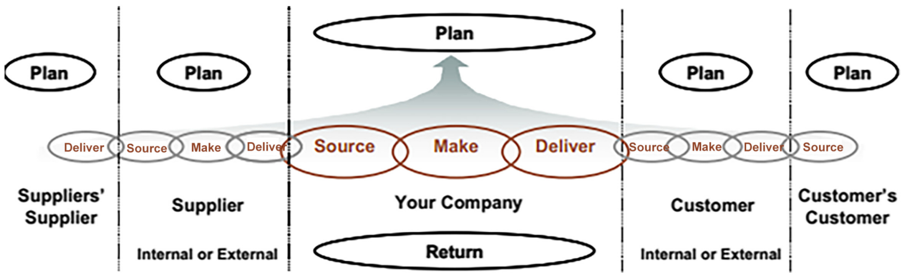
Supply chain performance measurement involves all component members of the supply chain, from the supplier to the consumer. Supply chain performance measurements include procurement, production planning, production, order fulfillment customers and returns (Pujawan and Mahendrawati, 2017).

Supply chain performance measurement is the process of examining a company's supply chain and deciding on what will be measured to determine the effectiveness of the supply chain. Supply chain performance measurement can be implemented at three different levels: strategic, tactical and operational. These metrics are often needed due to insufficient consistency or communication (Voss, 1988; Gunasekaran *et al.*, 2004; Katunzi, 2011 in Setiadi *et al.*, 2018).

Supply chain evaluation is a complex task because there are multiple influencing factors. These factors include lack of historical data, lack of cohesive metrics and poor communications on reporting consumer requirements. Traditionally, supply chain performance measurement has focused on cost, time and accuracy (see Figure 1).

### *2.2 Supply chain operations reference*

SCOR is a process reference model developed by Supply Chain Council as a diagnostic tool supply chain management. The SCOR model is a widely accepted industry reference model




**Source(s)**: Pujawan and Mahendrawati, 2017

**Figure 1.**
Core supply chain process

for SC operations that was introduced to assist organizations in mapping, developing and referencing SC operations and in assessing and monitoring levels of SC performance (SCP; Rotaru *et al.*, 2014). SCOR is also essentially a model-based process. The model integrates three major elements of management: business process re-engineering, benchmarking, and process management into a cross-functional framework in the supply chain (Bolstorff and Rosenbaum, 2003). These three elements are

(1) *Business process re-engineering* essentially capturing a complex process that occurs at this time (as is) and defines the desired process (to be)

(2) *Benchmarking* is an activity to obtain data on the operational performance of similar companies. The internal target is determined based on the performance of best in class acquired

(3) *Process measurement* serves to measure, control and improve supply chain processes.

SCOR divides supply chain processes into five core processes: plan, source, make, deliver and return. Plan is a process of balancing supply and demand to determine the best course of action to meet the needs of procurement, production and delivery. Source is the procurement of goods and services to meet demand. Make is the process of transforming raw materials/ components into the products desired by the customer. Delivery is the process of fulfilling the demand for goods or services. Return is the process of product returns or refurbishment (Pujawan and Mahendrawati, 2017).

SCOR performance measurement attributes consist of five elements, including reliability, responsiveness, flexibility/agility, cost and assets (Setiawan *et al.*, 2011). The fifth attribute is a supply chain performance measurement tool and divided into internal performance and external performance. The internal performance attributes are asset and cost, while the external performance attributes include reliability, flexibility and responsiveness. Reliability is the ability to accomplish the job as expected: in timely fashion, at the required quality and at the requested amount. Responsiveness is the speed of carrying out the work, among others, measured in the order fulfillment cycle time. Agility/flexibility is the ability to respond to external changes in order to stay competitive in the market. Cost is the cost to run the supply chain processes. "Asset" involves the capabilities to utilize assets productively. The following performance attributes will be added as performance metrics (Bolstorff and Rosenbaum, 2011).

*2.2.1 Reliability.* 2.2.1.1 Delivery performance. Delivery performance is calculated by dividing the total number of "on time" deliveries in a period by the total number of deliveries made. The result is then multiplied by 100 and expressed as a percentage.

$$\text{Delivery performance} = \frac{\text{total number of on time deliveries}}{\text{total number of deliveries made}} \times 100\%$$

Total number of on-time deliveries is the total ship delivered to the customer within a specified period "on time" in accordance the contract or agreement. Meanwhile, the total number of deliveries made within a period comprises both ships that were delivered on time and those which were not. Delivery performance is an indicator of how capable the traditional shipbuilding industry is to meet customer demand in terms of the requested delivery date (RDD). So, this instrument calculates the efficiency of supply chain processes in the traditional shipbuilding industry by calculating what percentage of ships can be delivered on time to the customer.

2.2.1.2 Perfect order fulfillment. Perfect order fulfillment is the percentage of orders delivered to the right place, with the right product, at the right time, in the right condition, to the right customer (in accordance with the standard). Failure to meet any of these conditions results in a less than perfect order.

$$\text{Perfect order fulfillment} = \frac{\text{total delivery in accordance with the standard}}{\text{total number of deliveries made}}$$

Total delivery in accordance with the standards represents the number of ships that can be delivered to the customer under the customer's standards. Standards demanded by the customers include the shape of the ships (Praharsi *et al.*, 2018), ships size (length, width, height, gross tonnage), production time, and the price of ship production. This instrument calculates how many ships were delivered and in accordance with the wishes of customers compared. The higher the percentage of these instruments, the better the shipbuilding industry's ability is to build ships according to customer standards.

2.2.1.3 Order fulfillment/fill rates. Order fulfillment is the simple way of measuring the product stock against customer order, or the percentage of total delivery of products according to demand and filled without waiting.

$$\text{Order fulfillment} = \frac{\text{Total product delivery}}{\text{total requested products}} \times 100\%$$

Total product delivery refers to the amount of ship requests received by the shipbuilding industry that could be completed without the customer having to wait, then the shipbuilding industry could produce immediately. Total requested products refer to all ship orders from customers to the shipbuilding industry in a specific time frame, including those that can be produced immediately and those that must wait for a turn. Since traditional shipbuilding industries have limited space to build ships, building several ships at once is extremely difficult. The traditional shipbuilding industries need to limit a certain number of ships that can be produced at a given time. The number of ships that can be delivered to a customer without causing backorders or losing sales is one of the order fulfillment performance attributes. The higher the percentage, the better the order fulfillment performance of its shipbuilding industries.

*2.2.2 Flexibility.* Flexibility is the average time needed by shipbuilding industries to respond when there is an uncharged increase or decrease to production specifications, such as changes in the keel length, ship shape and size. The shorter the response time to changes, the better the shipbuilding industry performance. Flexibility can be measured by counting the total time required for the work order changes written in units of days/months.

*2.2.3 Responsiveness.* 2.2.3.1 Order fulfillment lead time. Order fulfillment lead time refers to the amount of time it takes a shipbuilding industry to build a ship in order to fulfill customer orders.

$$\text{Order fulfillment lead time} = \text{order receiving time} + \text{order manufacturing time} + \text{order delivering time} + \text{delays time}$$

Order receiving time is the time required to receive ship orders and to process it. Order manufacturing time is the time required to produce the ships from preparatory work to finishing. Order delivery time is the time required to deliver a ship to the customer. Delay time is the time delay in producing the ships due to various factors, including the weather, the lack of labor productivity and run out of raw materials.

2.2.3.2 Order fulfillment cycle time. Order fulfillment cycle time is an attribute that calculates how long the shipbuilding industry took to produce the ships, starting from the customer making an order to the delivery stage without any time delay/delay time.

$$\text{Order Fulfillment Cycle time} = \text{order receiving time} + \text{the order manufacturing time} + \text{order delivering time}$$

*2.2.4 Assets.*

(1) *Cash to cash cycle time* measures the time required for the supply chain to convert its inventory into cash. There are three components in computing cash to cash cycle time: the average account receivable, the average account payable and inventory days of supply. The average account receivable means the speed of customer to pay for the received order. The average account payable means the speed of company to pay the raw materials/components to supplier. The formula of cash to cash cycle time is as follows:

$$\begin{aligned}\text{Cash to cash cycle time} = {} & \text{Inventory days of supply} \\ & + \text{average days of account receivable} \\ & - \text{average days of account payable}\end{aligned}$$

(2) *Inventory days of supply* measure the average time length of company holds inventory if there is no further replenishment. The formula is as follows:

$$\text{Inventory days of supply} = \frac{\text{Average inventory level}}{\dfrac{\text{Demand per year}}{\text{the number of working days in a year}}}$$

(3) Asset turn

Asset turn measures the effectiveness of the use of the entire assets of the shipbuilding industry in generating sales. The asset turn can be calculated using the following formula

$$\text{Asset turn} = \frac{\text{Sales}}{\text{average of total asset}}$$

Sales is the total sale of the ships in a certain period. Total assets are total assets owned by the shipbuilding industry to produce ships, such as grinding machines, drilling machines, hammers and chainsaws. Higher percentages of these attributes correspond to higher shipbuilding industry asset management effectiveness.

*2.2.5 Cost.* 2.2.5.1 Cost of good sales (COGS). COGS are all costs incurred in order to produce the ships from planning stage to finish product. The costs include the total cost of direct materials such as wood, nails, nuts, bolts, paint and total labor cost.

$$\begin{aligned}\text{Cost of Good Sales} = {} & \text{Cost Centers for Material} \\ & + \text{Cost Centers for Direct Manufacturing Labor} \\ & + \text{Cost Centers for Indirect Manufacturing Labor}\end{aligned}$$

2.2.5.2 Total supply chain management cost (TSCM). TSCM comprises the total direct and indirect costs of the ship, from the planning stage to the customer delivery stage. The calculated cost is the cost of planning, which includes expenses incurred to make the planning as the design drawings of ships: procurement costs are incurred for the purchase of raw materials ships such as transportation costs; holding cost is the cost of storage such as the cost of land lease, electricity or water to produce the ships; and delivery costs are costs incurred to deliver the products to customers.

$$\begin{aligned}\text{Total supply chain management cost} = {} & \text{Cost of Procurement} + \text{Planning Costs} \\ & + \text{Storage Cost} + \text{Delivery Cost}\end{aligned}$$

The percentage of TSCM is calculated by dividing the total revenue by the TSCM which is then multiplied by 100%.

After each supply chain performance matrix entry is measured and calculated, the resulting values are compared with the value superior SCOR card as the benchmark value. Benchmark value that is used in this study is a combination of Supply Chain Council and the measurement of supply chain at the company that is in the context of a competitive environment (Harrison and Hoek, 2008). Here are the criteria and benchmarking supply chain performance (see in Table 1).



| Attributes SCM | Performance indicators | Benchmarking Parity | Advantage | Superior |
|---|---|---|---|---|
| *External performance* | | | | |
| Reliability | Delivery performance (%) | 85.00–89.00 | 90.00–94.00 | ≥95.00 |
| | Order fulfillment performance (%) | 94.00–95.00 | 96.00–97.00 | ≥98.00 |
| | Perfect order fulfillment (%) | 80.00–84.00 | 85.00–89.00 | ≥90.00 |
| Flexibility | Flexibility (days) | 30.00–26.00 | 25.00–21.00 | ≤20.00 |
| Responsiveness | Order fulfillment lead time (days) | 7.00–6.00 | 5.00–4.00 | ≤3.00 |
| | Order fulfillment cycle time (days) | 8.00–7.00 | 6.00–5.00 | ≤4.00 |
| *Internal performance* | | | | |
| Asset | Cash to cash cycle time (days) | 80.00–47.00 | 46.00–29.00 | ≤28.00 |
| | Inventory days of supply (days) | 55.00–39.00 | 38.00–23.00 | ≤22.00 |
| | Turnover asset / asset turn | 8.00–11.00 | 12.00–18.00 | ≥19.00 |
| Cost | Total supply chain cost (%) | 13.00–9.00 | 8.00–4.00 | ≤3.00 |
| | Cost of Goods | ≥64.08 | 51.50–64.07 | 26.54–51.40 |

**Source(s)**: Harrison and Hoek (2008)

**Table 1.** Matrix supply chain performance measurement

Each product has different characteristics. Different characteristics of the product will cause differences in the determination indicator in measuring the performance of the supply chain (Yolandika *et al.*, 2016). According to Bolstorff and Rosenbaum (2011), after the values were measured, they will be compared to benchmark performance of the supply chain that have been set by the Supply Chain Council. A benchmark is a value standard used for measuring the performance of the supply chain. Benchmark consists of three classifications, namely parity, advantages and superior.

### *2.3 Supply chain performance in ETO strategy*

Engineering-to-order (ETO) is a manufacturing strategy that is based on design creation at the time of order by the customer. Basically, this strategy applies an irregular schedule in creating custom ETO products. Consequently, there is no regular material procurement schedule. Thus, it is important for the ETO company to foster good relationships with suppliers (Jagtap and Kamble, 2019; Zhang *et al.*, 2010). Besides a good relationship, the company must analyze its supply chain performance. As suggested by Gunasekaran *et al.* (2004), additional research and practitioners' initiatives are needed in the field of supply chain performance measurement. Thus, it is essential to draw new measurement design and programs for assessing the SCP, since every company needs distinctive method. Several methodologies have been used by ETO companies in measuring their SCP, including Strength, Weakness, Opportunity, Threat (SWOT) analysis, Key Performance Indicator (KPI), Performance Value Analysis (PVA) and Structural Equation Modeling (SEM), which can be seen in Table 2.

Table 2 has shown various methodologies that can be used by the ETO company to measure its performance of supply chain, and SCOR model is only one of them which is not listed in Table 2. To make it clearer, all the SCOR model implementation in ETO strategy will be explained thoroughly in Table 3. The research's object also varies from manufacturing,

**Table 2.** Literature review of supply chain performance in ETO strategy

| No | Author (Year) | Title | Research's object | SCP method | Result |
|---|---|---|---|---|---|
| 1 | Braglia *et al.* (2020) | Overall construction productivity: a new lean metric to identify construction losses and analyze their causes in engineer-to-order construction supply chains | Construction | Overall construction productivity | This study proposed a framework that was able to identify the losses in the ETO construction supply chain and define new metrics named overall construction productivity that could be suitable to quantify the overall impact of the identified losses. Based on the results obtained in the case study, OCP could evaluate the most significant causes of losses |
| 2 | Bäckstrand and Fredriksson (2020) | The role of supplier information availability for construction supply chain performance | Construction | Information availability | (1) The results showed:<br>(2) Lack of awareness toward information sharing within the construction industry was a greater problem for intermittent suppliers than continual suppliers, because intermittent suppliers have less access to the existing information due to their lack of presence and poor internal communication.<br>(3) Supplier could improve the information availability by increasing the service offering to customer (VMI service) |
| 3 | Raval *et al.* (2020) | The application of lean Six Sigma enabled organizational performance to enhance operational efficiency | Manufacturing | LSS, data envelopment analysis (DEA) approach with CCR and BCC models | The results have accommodated the manufacturing companies in determining the best practice units, the potential source of potential source of inefficiency and deliver beneficial data for the consistent enhancement of the operational efficiency. The managers and decision-makers have been supported by the DEA's results in deriving appropriate strategies to enhance their performance. It has proven that the DEA approach can be used as a benchmarking tool and open up discussion between academicians and practitioners regarding this issue |
| 4 | Salehzadeh *et al.* (2020) | Exploring the consequences of judgmental and quantitative forecasting on firms' competitive performance in supply chains | Manufacturing | Judgmental forecasting, quantitative forecasting, mixed forecasting, SEM | Three forecasting methods used in this study had positively affected the supply chain performance, such as cost reduction, efficiency enhancement and the customer satisfaction. These SC performance factors will also improve the organization competitiveness performance. Based on this study, it identified that the forecasting methods would help companies to meet their customer needs and lead to the better SC performance |

(*continued*)

| No | Author (Year) | Title | Research's object | SCP method | Result |
|---|---|---|---|---|---|
| 5 | Raval *et al.* (2019) | Benchmarking the lean Six Sigma performance measures: a balanced score card approach | Manufacturing | Balance scorecard | The proposed balance scorecard-based template had guided the LSS performance measurement to assist in development and implementation strategy on a continuous basis. Besides, a starting point has also been offered by this study for organizational benchmarking in terms of LSS performance measures adoption level |
| 6 | Jagtap and Kamble (2019) | An empirical assessment of relational contracting model for supply chain of construction projects | Construction project | CFA and SEM | The mediation analysis has identified project trust as a strong antecedent of establishing the client–contractor relationship in the project. The research study has identified the three mediators: the procurement-specific factors, the dyadic factors and relationship commitment. Thus, it can be concluded that project trust in the construction SC is necessary, but not the sufficient factor in successful project delivery. However, the procurement-specific factors involved in the project and the dyadic factor between the client and the contractors transform the projects trust into the project performance |
| 7 | Yildiz and Ahi (2019) | Innovative decision support model for construction supply chain performance management | Construction | ANP, TOPSIS, and DEMATEL | The result show that cash cycle time, return on working capital and perfect order fulfilment were the most important performance metrics, and companies should be aware of the performance of their supply chain processes before taking action for their redesign with an aim to achieve improvement |
| 8 | Romule *et al.* (2019) | Supplier performance assessment (evidence from a UK-based manufacturing company and its suppliers) | Manufacturing | Key performance indicator (KPI) | The fifth most critical dimension of supplier's performance measurement that is essential to business performance and operations include the net profits, flexibility and responsiveness, purchasing order, cycle time and SAP. The study suggested an inter-linkage between the qualities and SAP also between the net profits and capacity utilization |

(*continued*)

**Table 2.**

Table 2.

| No | Author (Year) | Title | Research's object | SCP method | Result |
|---|---|---|---|---|---|
| 9 | Soni and Kodali (2017) | A classification scheme for representing the variation in business and supply chain performance in Indian manufacturing industry | Manufacturing | ANOVA and Pearson | The result determined<br>(1) SC performance were identified in 4 dimensions (SC flexibility, SC integration, customer responsiveness, supplier performance)<br>(2) SCM practices (SCMPs) had a positive effect on SC performance (SCP) (H1), which, in turn, also positively affects manufacturing firm's performance (MFP) (H3). Despite this intermediary positive effect of SCMP on MFP through SCP, the study also suggested that SCMPs had a direct and positive effect on MFP (H2) |
| 10 | Zhou and Kohl (2017) | High-performance benchmarking of manufacturing processes with object-based modeling | Manufacturing (boat building) | Object-class-oriented modelling, benchmarking evaluation profiles and integrated enterprise modelling | It was proven in this study that the object-class-oriented modeling approach could be applied to manufacturing processes. As identified by this study, the higher the degree of independence in terms of locations, industry sectors and products, the more powerful and higher performance of benchmarking would be achieved. The benchmarking's performance level had been defined by proving and demonstrating the higher and lower performance levels. Furthermore, the high-performance benchmarking tool had been successfully applied to a production footprint case study |
| 11 | Taschner (2016) | Improving SME logistics performance through benchmarking | Manufacturing | KPI and root cause analysis (RCA) | This SC performance model stated several results, such as<br>(1) Since the SME's companies still lack the know-how to perform effective and effective benchmarking process, it is hardly possible to do both self-administered process and the fully automated benchmarking tools<br>(2) The relationship between the company strategy and the logistics function or unclear KPI definitions were still neglected<br>(3) The extension to a true supply chain benchmarking process model is difficult |

(*continued*)

| No | Author (Year) | Title | Research's object | SCP method | Result |
|---|---|---|---|---|---|
| 12 | Vlachakis *et al.* (2016) | A methodology for analyzing shipbuilding industry supply chains and supplier selection | Shipbuilding industry | Kraljic's matrix | The study identified the essential strategic cooperations between shipbuilding industry suppliers, since supplier improvement in terms of lead times and product quality were achieved. By implementing Kraljic's matrix in the material categorization process, this study identified that the SC performance could be improved by adjusting the best practices to the needs dictated each time by the project's specifications |
| 13 | Dubey and Ali (2015) | Exploring antecedents of extended supply chain performance measures: An insight from Indian green manufacturing practices | Manufacturing | Exploratory factor analysis (EFA), confirmatory factor analysis (CFA) and regression analysis | The result showed that the small and medium enterprises of Indian manufacturing had not recognized the real value in the implementation of the lean manufacturing practices and supplier relationship management. The essential determinants suggested by the factor analysis output were the total quality management (TQM), supplier relationship management (SRM), R&D and technology, the lean manufacturing practices. While the regression analysis output has further established that TQM, R&D and technology are strong determinants of the extended supply chain performance |
| 14 | Sillanpää (2015) | Empirical study of measuring supply chain performance | Manufacturing | New framework for SC measurement with the key elements which are defined as time, profitability, order book analysis and managerial analysis | In this framework, the supply chain was measured with the help of order book analysis, which leads to possibility in obtaining an overview of the order volumes, production volumes and on-time delivery of the case production plant. The indicators served well in practice when managers were managing and developing the supply chain. The most essential indicator in this study was the lead time |
| 15 | Wibowo and Sholeh (2015) | The analysis of supply chain performance measurement at construction project | Construction of road project | AHP, objectives matrix (OMAX) and traffic light | Based on scoring system performance of road project, scoring with OMAX and traffic light is 6.4 (maximum value 10). The result of performance measurement with scoring system of OMAX (objective matrix) and traffic light was in medium score, level 6, because several problems occurred when the project was ongoing |

(*continued*)

**Table 2.**

**Table 2.**

| No | Author (Year) | Title | Research's object | SCP method | Result |
|---|---|---|---|---|---|
| 16 | Sahu *et al.* (2014) | Supply chain performance benchmarking using grey-MOORA approach | Manufacturing | Grey theory, MULTIMOORA | The method proposed had facilitated a multi-criteria group decision-making (MCGDM) problem under uncertain environment and provides an appropriate compromise ranking order with respect to three available possible alternatives |
| 17 | Rymaszewska (2014) | The challenges of lean manufacturing implementation in SMEs | Furniture and motor boat manufacturing | Lean manufacturing | The authors studied the current company's situation and the results about the readiness of companies to implement lean and explore the challenges that might happen in lean implementation. Furthermore, the authors also addressed the suggestions to overcome the challenges |
| 18 | Ip *et al.* (2011) | Modeling supply chain performance and stability | Manufacturing | KPI, system dynamics, autoregressive integrated moving average (ARIMA) | (1) The most significant factors influencing the SC performance covered 2 KPIs (effectiveness and efficiency) with 6 corresponding indicators (product reliability, employee fulfillment, customer fulfillment, on-time delivery, profit growth and working efficiency)<br>(2) The combined model provided evidence that SC performance of the case company was up to standard (average OPIN¼0.64) and considered stable, but still far from outstanding. Continuous improvement, especially in supply chain efficiency, was suggested in order to maximize performance |
| 19 | Ramanathan *et al.* (2011) | Supply chain collaboration performance metrics: a conceptual framework | Manufacturing | Supply chain collaboration (SCC) | Performance at this stage of collaboration was measured through operational efficiency and risk/return ratio. 22 proposed metrics had been set to measure SC performance at its initial (pilot stage) and advanced stages in 2 case companies |
| 20 | Soni and Kodali (2017) | Internal benchmarking for assessment of supply chain performance | Manufacturing | Performance value analysis (PVA) and SWOT analysis | 73 performance measures were divided into 6 significant categories (facilities, information, inventory, pricing, sourcing and transportation) for 3 manufacturing companies in 3 different countries. In all, 18 of them showed consistent performance |

(*continued*)

| No | Author (Year) | Title | Research's object | SCP method | Result |
|---|---|---|---|---|---|
| 21 | Zhang *et al.* (2010) | Simultaneous configuration of platform products and manufacturing supply chains: comparative investigation into impacts of different supply chain coordination schemes | Manufacturing | SC coordination relationship<br>(1) Non-interactive supplier (NIS) scenario<br>(2) Non-cooperative supplier (NCS) scenario<br>(3) Cooperative supplier (CS) scenario | The results show that the manufacturer would prefer a cooperative relationship with its suppliers. Furthermore, with a higher level of supply chain integration, the manufacturer could serve the market with higher product variety |

**Table 2.**

**Table 3.** Literature review of SCOR in ETO strategy

| No | Author (year) | Title | Research's object | SCOR attributes | Result |
|---|---|---|---|---|---|
| 1 | Kottala and Herbert (2019) | An empirical investigation of supply chain operations reference model practices and supply chain performance. Evidence from manufacturing sector | Manufacturing | Reliability, responsiveness, flexibility, costs and assets | (1) Cost was chosen as the best practice in almost all the process<br>(2) Plan, source, make, deliver and return processes have positive influence on SC performance indicators (quality of goods, economic order quantity, cash to cash cycle time, delivery reliability, manufacturing lead-time, total cash flow time, inventory turnover ratio and warranty/returns processing cost)<br>(3) SCOR-based processes to be designed in SCPMS are the quality of delivery of goods, quality of delivery documentation, CC, manufacturing cost, timely available of accurate information, SATRTQP, inventory costs and ROC |
| 2 | Wen (2015) | Evaluation of supply chain performance for shipping industry by using AHP method | Shipping industry | Three aspects of SC performance and their variables are listed below<br>(1) Service effectiveness for shippers (SES): reliability and responsiveness<br>(2) Operation efficiency in providing the service (OE): costs and assets<br>(3) Service effectiveness for consignees (SEC): reliability and responsiveness | Performance indexes which gained the highest attention per each aspect are listed below<br>(1) Service effectiveness for shippers (SES): Fulfill the promise made to shippers<br>(2) Operational efficiency in providing services (OE): Reduce the logistics administration costs<br>(3) Service effectiveness for consignees (SEC): commitments to consignees |

(*continued*)

| No | Author (year) | Title | Research's object | SCOR attributes | Result |
|---|---|---|---|---|---|
| 3 | Rauch *et al.* (2015) | Synchronization of engineering, manufacturing and on-site installation in lean ETO enterprises | Manufacturing | Reliability, responsiveness, flexibility | JIT delivery is only possible with a high amount of inventory at the fabrication shop or at the construction site, due to long lead times in procurement, processing and assembly of components. In addition, engineering is not always ready with their technical solutions and drawings when they are needed to proceed in manufacturing or installation. Therefore, a lack in methods and instruments of synchronization between the single phases in the ETO value chain has been identified |
| 4 | Palma-Mendoza (2014) | Analytical hierarchy process and SCOR model to support supply chain redesign | Not mentioned (general) | Reliability, responsiveness, agility, SC cost, asset management | (1) No available methodologies on how to identify the relevancy, so the author recommended to use SCOR model to map the SC and combine both AHP with SCOR model to conduct selection target for re-design<br>(2) The AHP analysis had proven the calculation of a priority rank for the metrics criteria used was possible to identify the most crucial SCOR metrics associated with the redesign target |
| 5 | Öztaysi and Sürer (2014) | Supply chain performance measurement using a SCOR-based fuzzy VIKOR approach | Not mentioned (general) | Reliability, responsiveness, agility, costs, asset management | (1) Cost was chosen as the criteria which had the highest crisp weights in fuzzy AHP analysis result<br>(2) According to the integrated fuzzy VIKOR-AHP analysis result, the best performing supply chain was alternative 3, based on the expert judgments' voice |
| 6 | Hwang *et al.* (2014) | Operational performance metrics in manufacturing process: based on SCOR model and RFID technology | Manufacturing industry | Reliability, responsiveness, agility, costs and asset management | (1) Metrics like inventory management, cycle time management, pallet management, production process control, sorting order |

(*continued*)

**Table 3.**

Table 3.

| No | Author (year) | Title | Research's object | SCOR attributes | Result |
|---|---|---|---|---|---|
| | | | | | and production flexibility management were considered when designing the procedure of the performance measurement in ERP system<br>(2) In designing the performance measurement, the procedure only focused on the "Make" process as it included the operational metrics which represent the manufacturing process environment |
| 7 | Thunberg and Persson (2013) | Using the SCOR model's performance measurements to improve construction logistics | Construction industry | Reliability, responsiveness, agility, costs and assets | (1) The result of the study showed that the value of POF is 38%, SCT reached 134 min and the last CS spent EUR 249<br>(2) This study suggested five improvement regarding the source process, such as to improve the communication, predefine the material allocation, assess the supplier performance, verify and notify any deliveries and implement the SCOR model |
| 8 | Lepori *et al.* (2013) | Benefits and limitations of the SCOR model in warehousing | Logistics | SC delivery reliability, responsiveness, agility, costs and assets | The case study reveals the limitations of the model's application to distribution warehouses. The evaluation of the performance of certain processes and performance attributes is lacking. Monitoring a vast number of metrics is tedious; assistance in the selection of metrics or the definition of composite metrics is a research theme. A study on the computerization of this model could be envisaged as its manual application is time-consuming |

*(continued)*

| No | Author (year) | Title | Research's object | SCOR attributes | Result |
|---|---|---|---|---|---|
| 9 | Gosling *et al.* (2013) | A supply chain flexibility framework for engineer-to-order system | Construction industry | Flexibility | This study conducted in 2 construction supply chains involved 12 suppliers. The authors proposed a framework for achieving flexibility in the supply chain in the construction industry. There are four steps: (1) classify the supply chain, (2) identify and analyze uncertainties, (3) optimize pipelines, (4) develop strategic flexibility |
| 10 | Li *et al.* (2011) | Ensuring supply chain quality performance through applying the SCOR model | Manufacturing industry | Reliability, responsiveness, flexibility, costs and assets | (1) The crucial factors to significantly affect the customer-facing SC quality performance were regarding to the plan and source decisions. As for the internal-facing business performance, the make decisions was decided to be the most crucial factor<br>(2) Quality assurance, employee involvement and information sharing in the making process played significant roles to determine the internal-facing business performance |
| 11 | Zangoueinezhad *et al.* (2011) | Using SCOR model with fuzzy MCDM approach to assess competitiveness positioning of supply chains: focus on shipbuilding supply chain | Shipbuilding industry | Reliability, flexibility, costs, assets | (1) Six evaluation indexes were suitable for shipbuilding competitiveness positioning in terms of SCOR perspective. Those were value-added productivity, total logistics costs, inventory days of supply, perfect order fulfillment, cash-to-cash cycle time, and SC response time<br>(2) This study identified the relative importance of the four variables used, in order from the highest to the lowest after applying the FAHP concept: assets, costs, flexibility and reliability |

**Table 3.**

construction, shipping and in particular shipbuilding. Table 2 only fulfilled the manufacturing and construction sector with no specific paper discussing the shipbuilding sector. In this case, it can be defined that the SCOR model is preferably used to measure the supply chain performance of shipbuilding.

The literature review above has shown that there are limited papers which discuss SCOR in the shipbuilding sector from 2010 to 2021. Out of eleven papers reviewed in Table 2, only one detailed supply chain performance within the shipbuilding industry. However, this method is not applicable for certain types of shipbuilding in the industry, in particular for the wooden shipbuilding industry. Therefore, this study proposed new calculation metrics that suit the wooden shipbuilding industry in Indonesia, which is hoped to be of use for other wooden shipbuilding industries around the globe.

### *2.4 SCOR approach for shipbuilding company*

Since starting the study, it was known that not all of the SCOR metrics are reliable and compatible for implementation in shipbuilding construction, particularly for boat building in the traditional wooden shipbuilding industry. Therefore, this study proposes several new indicators to substitute for incompatible indicators. However, the proposal substitutes only two different SCOR attributes, which are "Responsiveness" and "Cost." The new approach used for the "Responsiveness" attribute is using the schedule performance index (SPI); meanwhile, the cost performance index (CPI) approach is used for the "Cost" attribute. These concepts will be further explained below.

*2.4.1 Schedule performance index.* SPI is a tool in project management for measuring the time effectiveness and efficiency to complete the project or ship. SPI is calculated by dividing the budgeted cost of work performance (BCWP) by the budgeted cost of work schedule (BCWS). The formula to calculate SPI is given below:

$$\text{Schedule performance index} = \frac{\text{BCWP}}{\text{BCWS}}$$

BCWP is the amount of budget that should be spent according to ship production performance and condition at a particular point. BCWS indicates the planned cost to produce the ship. SPI shows the progress compared to the planned ship project schedule. The SPI value should equal one (1). A value higher than 1 indicates the project ahead of schedule, while a value under 1 indicates the project is behind schedule. If the ship production finishes on schedule, it is delivered to the customer on time, and the event influences other attributes such as order fulfillment lead time.

*2.4.2 Cost performance index.* CPI is a tool in project management for measuring the financial effectiveness and efficiency of expenses spent on a project for example ship. CPI is calculated by dividing the BCWP by the actual cost of work performance (ACWP). The formula to calculate the value of CPI is given below:

$$\text{Cost performance index} = \frac{\text{BCWP}}{\text{ACWP}}$$

(BCWP is the amount of budget that should be spent according to ship production performance and condition at a particular point. The ACWP indicates the actual expenditure to produce the ship. The value of CPI should equal 1. A value higher than 1 indicates the project cost under the budget planning, while a value under 1 indicates the project cost more than budget planning.

## 3. Research methodology

Figure 2 shows the research methodology used in this study. First, we survey several shipbuilding industries, suppliers and customers. "Suppliers" are the shipbuilding industry's

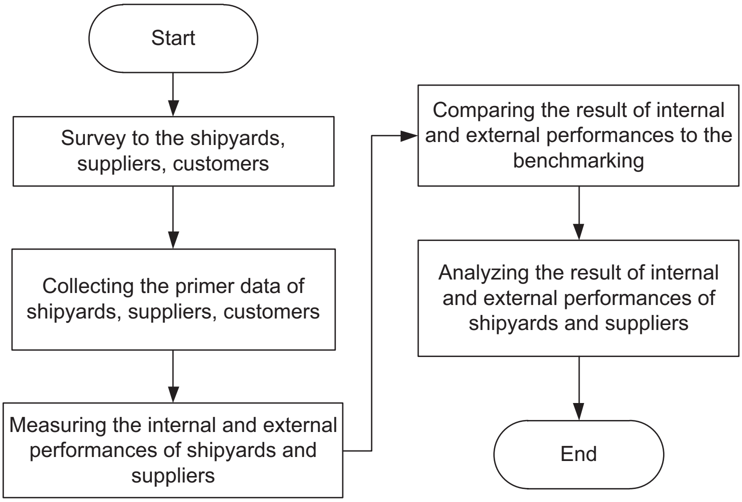



**Figure 2.**
Research methodology

material suppliers, such as machine, welding, wood, steel, and bolts and nuts suppliers. Meanwhile, "customers" are the buyers of the boats, such as the Department of Transportation, Marine Department and customers from the civil society. Secondly, we collected the primer data related to the input of internal and external performances' formulas. Primary data in this study were obtained through observations and interviews with shipbuilding industries, suppliers, and customers. Structured and in-depth interviews are used to obtain internal data and external performance shipbuilding industries, suppliers and consumers. Secondary data were obtained from the number of boats constructed in 2018–2019. All respondents in this study were selected intentionally or through purposeful sampling. Thirdly, we measured the internal and external performances of shipbuilding industries and suppliers. The internal performance attributes are costs and assets, while the external performance attributes include reliability, flexibility and responsiveness. Subsequently, we compare the results of their performances with the benchmarking. Finally, we analyze the results and discuss in detail their uniqueness.

## 4. Results and discussions

### *4.1 Supply chain performance of wooden shipbuilding industry*

Supply chain performance measurement is important to evaluate the input retrieval rate and used to improve the condition of the supply chain (Theeranuphattana and Tang, 2008). We measured supply chain performance using the SCOR matrix with two kinds of criteria: the external performance and internal performance. We can measure external performance by three attributes: reliability, flexibility and responsiveness. The internal performance can be measured by using two attributes: assets and cost. In this discussion, we will divide the performance of the wooden shipbuilding industry into two discussions based on external performance and internal performance. The information on the external performance wooden shipbuilding industry was obtained from a wooden ship's customers, while the information of the internal performance wooden shipbuilding industry was obtained from the owners themselves.

*4.1.1 Mapping of SCOR level 1.* The traditional wooden shipbuilding industry has involved some steps to adjust the supply chain in supporting its operational and production activity from the supplier to the customers (end user). Same as other shipbuilding industries, the wooden shipbuilding industry also has a simple supply chain path. This path involves three different flows, which are information and data flow, the material and product flow and money flow. Those three flows next are presented in Figure 3.

Firstly, information and data flow starts the whole traditional wooden shipbuilding industry business process. Since the shipbuilding industry is included as an ETO project, materials are not provided regularly. Materials will be provided when an order from the customer comes in. Therefore, the starting flow is the information and data sharing. It is initially delivered from any customer who needs a wooden boat, to the shipbuilding industry owner who is going to provide the boat. The customer will need to provide a boat specification list in the first place, so that the shipbuilding industry owner will produce the boat properly as required. Furthermore, this list will in the next step also help the owner to prepare the materials needed by ordering them through the supplier. This way, the owner will never get the excess or deficient materials.

The second flow, that is, of the material and product, starts from the supplier who has the role to supply any material needed by the shipbuilding industry owner. Since it is a traditional shipbuilding industry, the basic material needed is wood. Wood demand is managed through one distributor. The wood supply is ordered from the Indonesian State Forest Company, which in Indonesian is also known as "Perhutani," or from other local wood suppliers. The wood varies in type, but mainly the owner uses teak and mahogany as the main material in building the wooden boat. The wood length must be a minimum size of 70 cm. Meanwhile, the wood sample's diameter ranges from less than 20 cm to more than 40 cm (Praharsi *et al.*, 2019a, b). After sending the wood to the shipbuilding industry owner, the owner will cut the woods into proper size with the help of his workforce. The wood is not only cut, but is also processed into a boat. In contrast, if the wood is supplied from the Indonesian State Forest Company (Perhutani), the owner does not need to cut the woods again; in other words, the wood is ready to be used for building the boat. Basically, the owner could choose between two types of suppliers. Furthermore, if the owner urgently needs the wood and no wood supplier could fulfill his demand, the owner might cut the wood himself with his team (self-woodcutting). Due to the various materials used in building the boat, the owner must have a channel to several types of suppliers in providing the whole materials, which are divided into five types, such as the suppliers for machines, welding, wood, stainless steel and bolts and nuts. Finally, if the components have been assembled and the boat is ready to be used, it has to be quickly delivered to the customer before the deadline. Hence, the shipbuilding industry owner should schedule the whole process efficiently and effectively.

Last is the money flow, which is essential in an ETO strategy. This flow is divided into parallel steps. First is from the customer to the shipbuilding industry owner, which is usually done in progressions. This payment method is mainly decided by the customer's capability to pay the fee at once when the boat is ready to be used or by progress stages within the building time. As stated by the owner, if the customer chooses to pay it at once or at least gives a minimum 70% as the down payment, the wood's price will never go up.

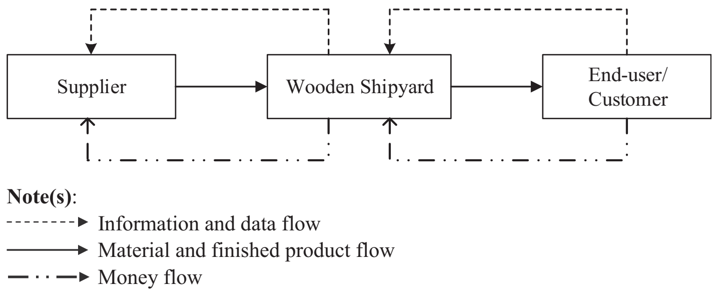



**Figure 3.**
General wooden shipbuilding industry supply chain

On the contrary, if the payment is made in advance, there will be no guarantee that the wood's price will be the same in the first place; although it depends on the market price, it tends to drastically increase each year. These types of payment also have been used by the government's shipbuilding company. The second money flow is from the shipbuilding industry owner to suppliers. This kind of payment usually is paid all at once, because the supplier tends to not deliver the materials until the payment is made. However, this case is different from the shipbuilding company owned by the government. If the customer does not pay fully at each stage, the company might owe money to its Korean supplier in advance and the money will be paid later when the government's company has received a full payment from the customer.

*4.1.2 Metric performance SCOR level 1.* The performance of the traditional shipbuilding industry supply chain will be measured by metric level 1 (one), which is related to the performance of the traditional shipbuilding industry in distributing ships to customers. Bolstorff and Rosenbaum (2003) explain that level 1 (one) analysis begins by defining the company's business goals. The supply chain evaluation is generally measured in line with the company's goals and main strategy.

Based on the results of interviews with traditional shipbuilding industry owners, it is stated that the business goals of the traditional shipbuilding industry are defined as follows:

(1) To make a profit

(2) To provide a level of service to customers that is on schedule and matching specification criteria.

The first goal is achieved by analyzing the values of the two attributes as follows:

(1) Supply chain cost

(2) Supply chain asset management

The second goal can be achieved by analyzing the value of other attributes such as:

(1) Supply chain reliability

(2) Supply chain flexibility

(3) Supply chain responsiveness

After knowing the business goals, the next step is to measure the metrics on SCOR according to the business goals. Based on the calculation, the metrics provided by SCOR can be seen in the actual data column in Table 4. The first business goals (1) use cost attributes which consist of COGS, CPI and asset turn indicators. Meanwhile, the second business goal (2) for calculating on schedule criteria uses some reliability attributes which consist of delivery performance indicators. Then, the flexibility attribute is also used for calculating on-schedule criteria that contain flexibility indicators. The last uses a responsiveness attribute counting the value of the SPI indicator. In addition, for calculating on specification criteria order fulfillment performance and perfect order fulfillment (POF) indicators are used.

After getting the actual score on each indicator, the next step is to determine the actual position and set the target performance for each metric based on the benchmark data.

*External performance supply chain* can be measured by using six metrics. The six metrics can be derived from the three attributes of external supply chain performance. They are delivery performance, order fulfillment performance, perfect order fulfillment, flexibility, order fulfillment lead time and order fulfillment cycle time.

*Delivery Performance.* Delivery performance is a performance measurement attribute that shows reliability to meet customer demand on time. Based on the average value of

| SCM attributes | Indicator | Parity | Benchmark Advantage | Superior | Actual score |
|---|---|---|---|---|---|
| *External performance* | | | | | |
| Reliability | Delivery performance (%) | 85–89 | 90–94 | ≥95 | 90% |
| | Order fulfillment performance (%) | 94–95 | 96–97 | ≥98 | 88% |
| | Perfect order fulfillment (%) | 80–84 | 85–89 | ≥90 | 100% |
| Flexibility | Flexibility (months) | 3 | 2 | 1 | 1 |
| Responsiveness | Order fulfillment lead time (months) | 7–6 | 5–4 | ≤3 | – |
| | Order fulfillment cycle time (months) | 8–7 | 6–5 | ≤4 | – |
| | Schedule performance index | <1 | 1 | >1 | 0.966 |
| *Internal performance* | | | | | |
| Asset | Cash to cash cycle time (days) | 80–47 | 46–29 | ≤28 | – |
| | Inventory days of supply (days) | 39–55 | 23–38 | ≤22 | – |
| | Asset turn | 8–11 | 12–18 | ≥19 | 20.8 |
| Cost | Cost of goods sales (%) | ≥64.08 | 51.5–64.07 | 26.54–51.4 | 76.92% |
| | Total supply chain cost (%) | 13–9 | 8–4 | ≤3 | 2.12% |
| | Cost performance index | <1 | 1 | >1 | 0.956 |

**Table 4.**
SCOR metric model level 1

shipbuilding industry delivery performance shown in Table 4, the delivery performance is in the position of advantage with a value of 90%. It shows that the ability of shipbuilding industries in delivery performance is good enough. The advantage level is intermediate targets and if the company is able to attain it, it is good for the company as it still has a chance of being increased to achieve the maximum performance targets (Setiawan *et al.*, 2011). The speed of delivery of traditionally made ships depends on several conditions. Since the ship is constructed by hand, many unpredictable factors can affect the completion of the ship, which include the state of the tide, the weather and other unforeseen circumstances. In addition, having no set delivery time agreed upon in the contract can cause delays. Spoken agreements between the shipbuilding industry owner and local suppliers are often preferred over formal contracts. As a result, shipbuilding industry's delivery performance improvements are limited.

*Order fulfillment*. Order fulfillment performance is the percentage of consumer demand that can be met from all the requested boats, written in percent (Setiadi *et al.*, 2018). Order fulfillment performance shows the capabilities of the shipbuilding industry to meet and to deliver customer demand. The better the score of order fulfillment, the better the performance achievement supply chain. In Table 4, order fulfillment is in the parity position with 88% score, which means that until now shipbuilding industry could not meet expected customer orders. The limitations of the shipbuilding industry equipment and manufacturing facilities, as well as the slow human capital regeneration, are customer order fulfillment barriers. The shipbuilding industry equipment available only allows for two or three ships to be serviced at once, depending on the size of the ship, so it is difficult for the shipbuilding industry to receive orders from customers at the same time. The manufacturing equipment used in shipbuilding industries is still conventional; for instance, wood dryers, trackers and bending machines. The use of conventional equipment and machinery makes the process take longer.

*Perfect order fulfillment*. A key to customer satisfaction is the suitability of the product received based on the wishes of the customer (Apriyani *et al.*, 2018). Based on the average value of conformity to the standards shown in Table 4, compliance with the standards is in a superior position with a value of 100%. This shows that wooden ship construction can proceed under a control system from the customer according to their needs, so that the ship will be useful and purposeful to the customer. This is a way of making customers satisfied with the products of the shipbuilding industry.

*Flexibility*. According to Upton (1995), flexibility is defined as the "ability to react or transform (supply chain processes) with fewest penalties in time, cost, and performance." Based on the shipbuilding industry performance flexibility score shown in Table 4, the time to respond to a ship order change by the shipbuilding industry is 1 month except for hull form. This is due to the fact that most of the human resources in the shipbuilding industry have over 10 years of experience in creating ships, and can easily understand and respond to customer wishes.

*Order fulfillment cycle time*. Every single order fulfillment period shows how long it takes a shipbuilding industry to fulfill one order. The lower the value of the order cycle, the better the performance of the supply chain (Apriyani *et al.*, 2018). According to Praharsi *et al.* (2019a), order fulfillment cycle time is on average 51–70 GT with the result of 8–11 months; meanwhile, on average 31–50 GT and 15–30 GT have the results of 5–8 months and 2–5 months, respectively. For the majority of the boats sized less than 15 GT, the results are 1, 5 and 10 GT with the order fulfillment cycle time results of 2 weeks, 1 month and 2 months, respectively. Because the order fulfillment cycle times vary according to the GT sizes of the boat, the benchmarking comparison cannot be done.

*Order fulfillment lead time*. The average time to meet customer requests in supply delivery is an indicator used to evaluate how responsive the wooden shipbuilding industry is to customers. The shorter the time required in fulfilling an order, the better will be the supply chain (Mutakin and Hubeis, 2011). The order fulfillment lead time is similar to the order fulfillment cycle time, except that it includes delays. Usually, such delays result from weather conditions: waiting is required before the shipbuilding industry can begin to manufacture, carry out sea trials or perform post-manufacturing fitting out. In some cases, such as with wooden boats, the manufacturing process may be entirely dependent upon the available seasonal weather conditions. Such delays also occur to prevent other related risks, such as electrical equipment exposure to rain. On average, the delay time lasts from 1 week to 2 months. Due to these unpredictable factors, order fulfillment lead time cannot be used for benchmarking.

*Schedule performance index*. The calculation of the estimated project performance is based on the time required for project completion compared to the originally planned time. SPI $< 1$ means that the project is delayed, and SPI $> 1$ means the project can be completed before the planned time. Based on Table 4, it is found that the SPI value is 0.966 which is in the parity position and means that the project is experiencing delays. Usually, project delays are caused by several factors, namely (1) temporary suspensions due to outdoor rain, as construction occurs outside, (2) personnel shortages in the shipbuilding process when workers suddenly stop working and (3) worker aesthetic standards when making rudder parts, which exceed customer standard and require longer processing time.

*Internal performance of the supply chain* measures the resources of the shipbuilding industry itself. It can be measured by using two attributes: asset and cost. Derivatives of these two attributes are five metrics that will be used for internal performance evaluation of the supply chain at the shipbuilding industry. The following five metrics used are cash to cash cycle time, inventory days of supply, asset turn, cost of goods, the total supply chain cost.

*Inventory days of supply*. Inventory days of supply is a supply chain management performance indicator that measures the time the shipbuilding industry can function with the current inventory on hand. Traditional shipbuilding industries do not have an inventory of finished products because they use the ETO principle, which is the practice of waiting for customer orders before building an engineer-to-order ship. The aim of the supply chain is to make sure the product is in the right place and time to meet consumer demand and make sure of no excess inventory or less (Srihartati, 2004). Therefore, the traditional shipbuilding industries do not have inventory days of supply as a metric for internal performance measurement of the supply chain.

*Cash to cash cycle time*. For each supply chain member, the cash to cash cycle time is their total time taken for payment to be received from and sent to partners. The quicker the conversion time, the less time inventory is spent in holding and the more efficiently the supply chain operates (Pujawan and Mahendrawati, 2017). To decrease the cash to cash cycle time, the owner and customer can negotiate payment terms. Most traditional shipbuilding industries ask for a down payment from customers prior to manufacturing. If the customers are willing to pay 70% of the total cost at the down payment, the shipbuilding industries guarantee no price increase incurred at the delivery process. Another term of payment is divided into several stages which are implemented prior to each task in the traditional boat building process, such as hull construction, frame installation, hatch installation, wheelhouse building installation, machine installation, painting and sea trial. Moreover, we cannot determine the exact average of the customer accounts receivable days due to varying terms of payment and boat sizes, which impact manufacturing time. Besides average days of account receivable, the formula cash to cash cycle time also considers other two components, namely inventory days of supply and average days payable. Traditional shipbuilding industries do not have inventory days of supply. Furthermore, the average day payable to the wood supplier varies according to the account receivable from shipbuilding industry' customer. Therefore, the cash to cash cycle time at the shipbuilding industries cannot be compared with standard benchmarking.

*Asset turn*. Asset turnover measures the company's ability to generate sales from total assets. According to Bolstorff and Rosenbaum (2003), asset turn is calculated by dividing revenue by the average of total assets including both working capital and fixed assets. The faster the assets turn, the bigger the company's revenue. Table 4 shows the value of the asset turnover was 20.8 which shows the shipbuilding industry was at superior. Shipbuilding industry asset turnover was high and effective due to the firm's lack of capital assets. The shipbuilding industry did not have any fixed assets such as land, buildings and machinery. Most shipbuilding industries rent the dockyard and excavator for daily sea trials and will move with their teams where the customers place an order. In addition, the shipbuilding industries normally do not keep finished product inventory. The impact of this high turnover has greatly influenced the profit margin of the shipbuilding industries.

*Cost of goods*. Cost of goods measures the direct cost of materials and labor to produce a product or service (Bolstorff and Rosenbaum, 2003). Table 4 shows the cost of goods is 76.92%, which means the costs involved in producing a boat is 76.92% of the revenues. This value is included in the category of parity, because the materials cost such as of teak and mahogany woods are always increasing. Moreover, standard labor costs per day differ between beginner, medium and expert personnel, and grow as well. Therefore, the shipbuilding industry avoids asking the credit from banks as their capital because they have to pay the interest. The consequence is decreased revenue. The capital is from the customers themselves with several terms of payment mechanisms.

*Total supply chain cost*. These are costs associated with operating the supply chain (Bolstorff and Rosenbaum, 2003). The total supply chain cost measures the cost from supplying raw material to the boat handing to the customer. Total supply cost includes procurement costs, transportation costs, planning costs, storage costs, and delivery costs. Considering the transportation cost for each supply of raw materials, the storage cost for renting the dockyard and the delivery cost for lowering boats into the sea/sea trials for 6 working days in one year, the total supply chain management cost is 2% as can be seen in

Table 4. We can conclude that the shipbuilding industry management fees are superior. A good supply chain could use the funds as efficiently as possible.

*Cost performance index*. The calculation of estimated project performance based on the costs required until project completion is compared with the originally planned budget. The values of CPI are greater than 1.00 which shows that value of the work that has been carried out is higher than the amount of money spent. So, the efficiency of using project resources is favorable (Khamidi *et al.*, 2011). Based on Table 4, it shows that the CPI value is 0.956 which is in the parity position and means that the project has cost overruns. This is because there is an additional duration of delay that exceeds the planned duration.

Based on Table 4, the actual data on the traditional shipbuilding industry show that the COGS metric is in a parity position. While the first goal of traditional shipbuilding industry is to gain profit, it must increase its performance target to a superior position. Besides that, the asset turn metric is in a superior position which means it is in line with the main goals of traditional shipyard. In addition to the COGS and asset turn metrics, the traditional shipbuilding industry also uses the CPI metric with a target of >1 which means the actual costs are less than the budgeted costs or at least = 1, which means the actual costs are the same as the budgeted costs. However, in actual conditions, the CPI of the traditional shipbuilding industry has a value of <1 which means that the cost of the traditional shipbuilding industry process is more than the planned cost.

The second traditional purpose of a shipbuilding industry is to provide a level of service to customers with set criteria. These criteria typically involve scheduling, being on-budget and specifications, measured through the delivery performance metrics, order fulfillment performance (OFP), perfect order fulfillment (POF) and SPI. In actual data, the delivery performance metric is in a position of advantage, which is very much in line with the targets set by the shipbuilding industry. Meanwhile, the OFP metric is in a position below parity, which has not reached the second goal of the traditional shipbuilding industry. Thus, traditional the shipbuilding industry must improve their performance at a parity position. This is different from the POF metric which is already in a superior position, which means that traditional the shipbuilding industry can already achieve their second business goal. Lastly, the SPI metric with a target in advantage position (=1) means that the actual time is the same as the planned time to finish the ship project. However, in actual conditions, the SPI of the traditional shipbuilding industry has a value < 1, which indicates that the duration of the ship project is delayed.

The next step is to measure a gap analysis to calculate the difference in value between the actual and targeted positions. The magnitude of this difference translates into the amount of increased income, if the performance is increased until it reaches the target (Bolstorff and Rosenbeum, 2003). After the gap for each indicator is calculated, any insufficient metrics can be identified. Once this has been done, the company can calculate the potential profit that could be earned if they were to achieve the targeted position. In order to perform these calculations, the company requires data on the values of total profit and gross profit margin for each product (Bolstorff and Rosenbaum, 2003). Table 5 shows the gaps and opportunities for OFP, COGS, SPI and CPI metrics obtained from the calculations in Tables 6–9.

Based on the table above, we got the opportunity from several metrics as follows

OFP metrics has an actual value of 88% and a target value of 94% so that the result shows a gap between actual and the target value of 6% and an opportunity of Rp42,936,668 which is obtained from the calculation of Table 6. This shows that with a 6% gap, the traditional shipbuilding industry company must increase its revenue by Rp42,936,668 so that the company can reach the targeted parity position.

Cost of goods sales (COGS) metrics has an actual value of 76.92% and the target value of 51.4%, so that the result shows a gap of 25.52% between actual and target values and an opportunity of Rp160,709,087 obtained from the calculation of Table 7. This shows that with

**Table 5.**
Gap and opportunities of metrics performance

| SCM attributes | Indicator | Benchmark Parity | Advantage | Superior | Actual score | Requirement gap | Opportunity |
|---|---|---|---|---|---|---|---|
| *External performance* | | | | | | | |
| Reliability | Delivery performance (%) | 85–89 | 90–94 | ≥95 | 90% | – | – |
| | Order fulfillment performance (%) | 94–95 | 96–97 | ≥98 | 88% | 6% | Rp42,936,668 |
| | Perfect order fulfillment (%) | 80–84 | 85–89 | ≥90 | 100% | – | – |
| Flexibility | Flexibility (months) | 3 | 2 | 1 | 1 | – | |
| Responsiveness | Order fulfillment lead time (months) | 7–6 | 5–4 | ≤3 | – | – | – |
| | Order fulfillment cycle time (months) | 8–7 | 6–5 | ≤4 | – | – | – |
| | Schedule performance index | <1 | 1 | >1 | 0.966 | 0.0034 | Rp82,112,500 |
| *Internal performance* | | | | | | | |
| Asset | Cash to cash cycle time (days) | 80–47 | 46–29 | ≤28 | – | – | – |
| | Inventory days of supply (days) | 39–55 | 23–38 | ≤22 | – | – | – |
| | Asset turn | 8–11 | 12–18 | ≥19 | 20.8 | – | |
| Cost | Cost of goods sales (%) | ≥64.08 | 51.5–64.07 | 26.54–51.4 | 76.92% | 25.52 % | Rp160,709,087 |
| | Total supply chain cost (%) | 13–9 | 8–4 | ≤3 | 2.12% | – | – |
| | Cost performance index | <1 | 1 | >1 | 0.956 | 0.044 | Rp106,046,189 |

a 25.52% gap, the company needs to increase its revenue by Rp160,709,087, so that the company can achieve the superior position as targeted.

When an evaluation was carried out at the end of the project plan duration, it was found that the budget spent on project work had not fulfilled the target budget for project completion. With the difference in the budget of Rp. 82,112,500.00, this means that the project cannot be completed at the end of the project plan duration.

When an evaluation is carried out at the end of the project plan duration, it is found that the actual costs spent on project work have exceeded the planned project completion budget target even though the project has not been completed in its entirety. With a difference in cost of Rp. 106,046,188.56, this means that the project is losing money.

*4.1.3 Mapping of SCOR level 2.* Figure 4, which identified the SCOR process for level 2, shows the processes that occur in the supply chain. The process starts from processes related to suppliers, production preparation activities, warehouse activities, ship production activities and ship delivery to customers. The level 2 SCOR mapping process only

| | |
|---|---|
| Total income (Rp) | Rp2,728,500,000 |
| OFP actual (%) | 88% |
| OFP target (parity); % | 94% |
| Total income × ((100−OFP actual)/100) (*a*); Rp | Rp2,728,500,000 |
| Total income × ((100−OFP target)/100) (*b*); Rp | Rp2,914,534,091 |
| Difference (*a*) dan (*b*); Rp | Rp186,034,091 |
| Gross profit (%) | 23.08% |
| Gross profit × difference (*opportunity)*; Rp | Rp42,936,668 |

**Table 6.** Opportunity calculation for OFP

| | |
|---|---|
| Total income (Rp) | Rp2,728,500,000 |
| COGS actual (%) | 76.92% |
| COGS target (superior); % | 51.4% |
| Total income × COGS actual (*a*); Rp | Rp2,098,762,200 |
| Total income × COGS target (*b*); Rp | Rp1,402,449,000 |
| Difference (*a*) dan (*b*); Rp | Rp696,313,200 |
| Gross profit (%) | 23.08% |
| Gross profit × difference (*opportunity)*; Rp | Rp160,709,087 |

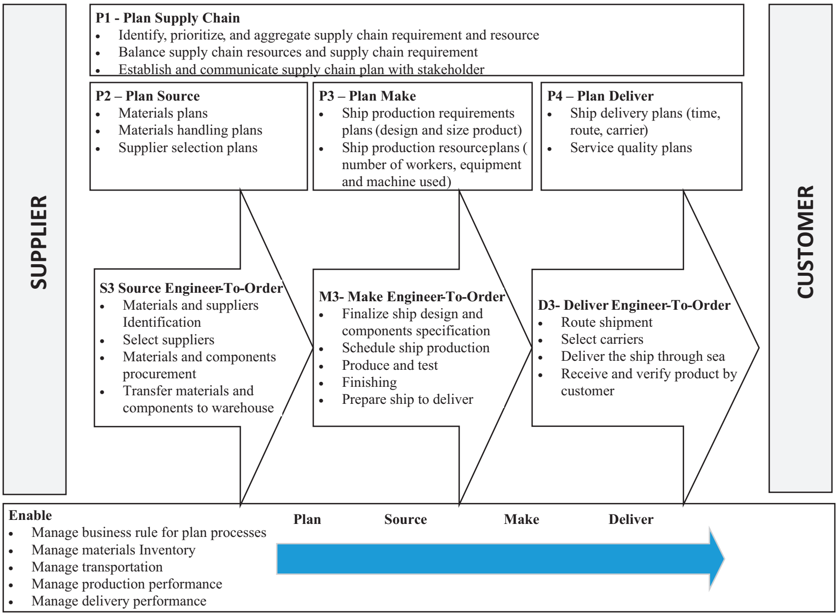
**Table 7.** Opportunity calculation for COGS

| | |
|---|---|
| Total plan budget (Rp) | 2,392,475,000,00 |
| CPI actual (index) | 0.966 |
| CPI target (index) | 1 |
| Total budget × (1−CPI actual) (*a*); Rp | 82,112,500,00 |
| Total budget × (1−CPI target) (*b*); Rp | - |
| Difference (*a*) and (*b*) (opportunity); Rp | 82,112,500,00 |

**Table 8.** Opportunity calculation for SPI

| | |
|---|---|
| Total plan budget (Rp) | 2,392,475,000,00 |
| SPI actual (index) | 0.956 |
| SPI target (index) | 1 |
| Total budget × (1−SPI Actual) (*a*); Rp | 106,046,188,56 |
| Total budget × (1−SPI Target) (*b*); Rp | – |
| Difference (*a*) dan (*b*) (opportunity); Rp | 106,046,188,56 |

**Table 9.** Opportunity calculation for CPI




**Source(s)**: Expert Interview

**Figure 4.**
SCOR process level 2

contains plan, source, make, and deliver because there is no return process at the shipbuilding because the ship is classified as an ETO item which requires high costs. In the ship production process, customers tend to carry out inspections every few weeks to check progress: if there are no adjustments to ship specifications according to customer wishes, the shipbuilding industry will immediately make repairs.

Mapping level 2 is carried out by interviewing some experts at the shipbuilding who are directly related and understand the process. The level 2 SCOR process is mapped based on the SCOR Model Version 10 from the Supply Chain Council. Each level 2 process can be further described by type below:

4.1.3.1 Planning. Plan supply chain is a process that aligns expected resources to meet expected demand requirements. The planning process consists of the following.

*4.1.3.1.1 Plan source.* Planning for the materials used in ship production such as wood, nails, bolts, paint, and others, planning the material handling in warehouse and planning the supplier selection such as identify the supplier criteria.

*4.1.3.1.2 Plan make.* Planning for the ship production requirements such as design and specification of the ship and plan the ship production resource such as workers and machines used for production.

*4.1.3.1.3 Plan deliver.* Planning for ship delivery and service quality.

4.1.3.2 Execution. Execution is a process that changes the state of material goods into finished products. In the execution process, this research would use ETO based on supply chain strategy in shipbuilding because the characteristic in shipbuilding is customer requirement driven, sourcing new materials and long lead-times. The execution process generally involves the following.

*4.1.3.2.1 Source engineer-to-order.* This process consists of (1) identifying the material that would be used in the ship production and also identifying some potential suppliers,

(2) selecting the reliable supplier based on criteria such as speed, price and quality, (3) procuring materials and components from selected suppliers, (4) transferring the materials and components into the warehouse.

*4.1.3.2.2 Make engineer-to-order.* This process consists of (1) finalized ship design and component specification based on customer request, (2) schedule ship production based on the type of ship, size and the number of workers, (3) produce ship from cutting wood to painting, (4)) sea trial of the ship as a finishing process, and (5) preparing the ship to deliver.

*4.1.3.2.3 Deliver engineer-to-order.* This process consists of (1) selecting the potential route shipment, (2) delivering the ship through the sea, (3) finally, the customer would receive and verify the specification of the ship based on agreement.

4.1.3.3 Enable. Enable is a process that prepares, maintains or manages information or relationships on which execution processes rely. Some processes in enable are managing business rule for plan process, materials inventory, transportation, production performance and delivery performance.

*4.1.4 Mapping of SCOR level 3.* Level 3 analysis is carried out to see in more detail the "make" process, because from the results of metric performance analysis in Table 4, the metric value of the cost of goods has the lowest performance. Level 3 mapping consists of all activities that occur in the make process, which is shown in Figure 5. This figure shows the ship production process from the beginning until the finished product in a traditional wooden shipbuilding industry which consists of input, process element and output. Mapping level 3 in the make process aims to find the cause of the low metric cost of goods, or in other words, the high cost of ship production.

These are the inputs in the make process:

(1) Identify production requirements

This process consists of identifying, prioritizing and considering as a whole with constituent parts, all sources of demand to produce a ship based on customer requirements.

(2) Identify production resources

This process consists of identifying, evaluating and considering all things that add value in the creation of a ship, such as the materials and components.

(3) Production plan

This process consists of the plan to produce a ship in specified time periods based on customer agreement. The plan consists of cutting wood, hull construction, frame installation, hatch installation, wheelhouse building installation, machine installation, painting and sea trials.

(4) Make information

This process consists of data collection related to information needed in ship production such as the number of workers needed, material needed, and others.

(5) Schedule production deliveries

Scheduling and managing the execution of the ship production against the customer agreement. The requirements for product deliveries are determined based on the detailed sourcing plan.

The "Make Engineering-To-Order" process breaks down, as seen in Figure 5, and here is the further explanation:

(1) *Finalize ship production engineering*: In this process, the worker will finalize the design and component specification of the ship based on customer wishes.

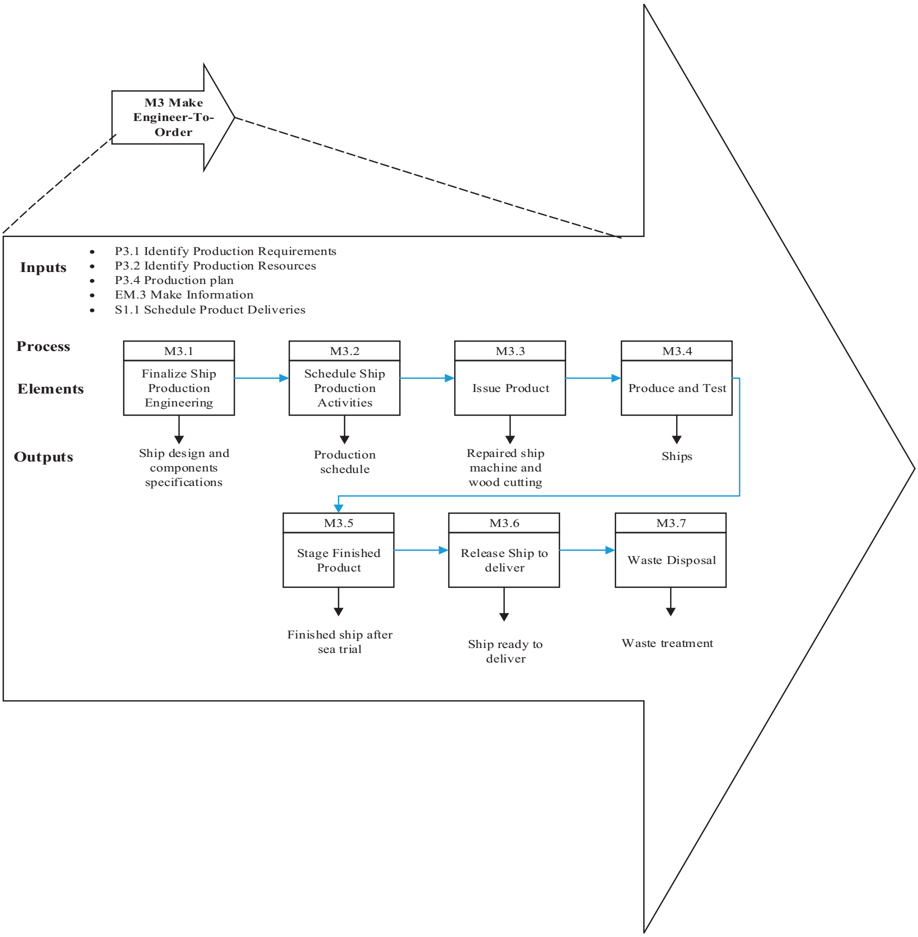



**Figure 5.**
SCOR level 3

**Source(s)**: Expert Interview

The customers have different ship specification requirements, such as the type of ship, size and machines used.

(2) *Schedule production activities*: In this process, the company makes a production schedule based on ship production activities, which could determine the production performance, and means the difference between planning and realization.

(3) *Issue product*: In this process the company would repair ship machines that will be used, because the company does not always buy new machines and prefers to buy used truck machines from Singapore that are still fit for use with a maximum age of 5 years. As a result, repairing these machines is necessary.

(4) *Produce and test*: In this process, there are five steps to produce the ship: cutting wood, hull construction, frame installation, hatch installation, wheelhouse building installation, machine installation, painting and sea trial. This series of activities precedes the finalization process and ship testing.

(5) *Stage finished product*: In this process, which produces the finished ship after the sea trial output, finalization in the production process is carried out, such as painting the ship, and performing tests such as speed tests.

(6) *Release ship to deliver*: In this process, the output ship is ready to deliver. It consists of preparing documents for shipping until the ship is delivered to the customer.

(7) *Waste disposal*: In this process, activities associated with collecting and managing waste produced during the produce and test processes are carried out. This involves waste treatment output for the remaining materials used in shipbuilding, such as wood chips and paint cans.

The package process is not included in level 3 of make engineering to order, because wooden ship products do not require packaging.

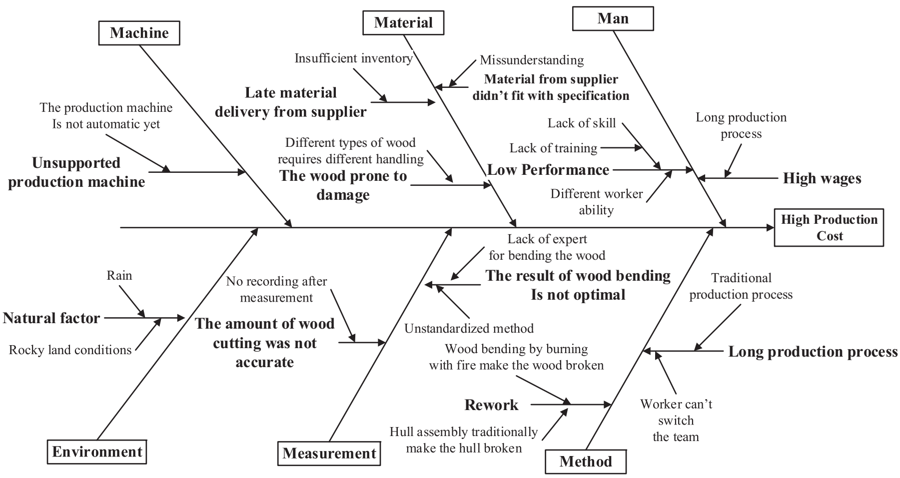
Based on the results of interviews with experts, information was obtained that the problem in the process element is the M3.4 or produce and test process. A fishbone diagram is presented in Figure 6 based on expert interviews about the problems that caused the high production cost.

Here are the further explanations from the fishbone diagram in Figure 6.

4.1.4.1 Man. In the human factor, two problems impact the high production cost of shipbuilding, which are the following.

*4.1.4.1.1 Low performance.* There are two causes of low worker performance. Firstly, different worker ability in the ship production process. There are 5–7 people who work at ship production in shipbuilding. Each worker has a different ability and is classified into a beginner, medium or expert level. Beginner workers tend to have lower performance than medium and expert workers due to lack of skills. In the case of shipbuilding, owners tended to hire workers with whom they had personal acquaintance, rather than recruitment by skill and ability. As a result, the workers did not have adequate skills, and this affected the speed at which ships were built. Secondly, lack of skill occurs in traditional shipbuilding due to a lack of regular training programs.

*4.1.4.1.2 High wages.* The high wages of workers are a major factor in the high cost of ship production. The main cause of high wages is the long production process. The wages of




**Source(s)**: Expert Judgments

**Figure 6.**
Fishbone diagram

workers for traditional shipbuilding industry are calculated on a daily basis, so that the longer the production process, the higher the labor wages will also be. There is only one expert and several beginner and medium workers that produce one ship. The production process cannot be maximized, especially if there are mistakes made by beginner workers. It could cause rework and increase production time. The increase of production time eventually causes a long production process which causes the high wages.

4.1.4.2 Material. In the material factor, there are two problems that impact the high production cost of shipbuilding, which are as follows.

*4.1.4.2.1 Late material delivery from supplier.* Due to the late arrival of materials, the ship production schedule might not be met. The main reason for this involves out-of-stock materials and subsequent delayed transportation of the material to the building site. In this case, the supplier should be chosen with care, and sufficient buffer times for the production process should be reserved.

*4.1.4.2.2 The wood prone to damage.* The basic material used in the ship is wood, and the wood cost is quite high. However, different types of wood need different handling, and incorrect handling makes the wood prone to damage. The different types of wood refer to their different sources of acquisition. There are two locations for obtaining the teak wood: from the Indonesian State Forest Company (Perhutani) and the self-wood-cutter; as a result, the quality of each wood is different. The type of teak wood from the Indonesian State Forest Company is well-dried, so that it can be directly produced, while the self-obtained teak wood, from the forest has a cheaper price but has not been dried properly; hence, the shipbuilding industry must handle the teak wood appropriately to avoid production defects. Furthermore, different types of teak wood also have different knots. Knots in the teak wood need special handling to avoid the wood being broken; for example, workers should nail the knots to strengthen them for ship production. However, some workers, especially beginners, still do not know how to handle each type of wood. Thus, wood handling errors could increase production costs.

*4.1.4.2.3 Material from supplier did not fit with the specification.* The shipbuilding owner orders wood from suppliers via telephone without written agreement, which can cause a lot of misunderstandings. The supplier only shows pictures of the wood to the owner without explaining specifications such as width and height, therefore the wood may not fit with the wishes of the shipbuilding owner when it is delivered to the production facility. However, because of no written agreement, the owner cannot return the wood to the supplier, despite being able to buy the wood at a low price. Wood specifications that do not fit with specifications make the ship production longer, requiring the workers to join pieces to make them wider. Subsequently, lengthened ship production times could increase the wages of workers, thus increasing production costs.

4.1.4.3 Machine. For the machine factor, shipbuilding production cost problems involve non-automatic machines that can increase the speed of the shipbuilding process. The non-automatic production machines include wood dryer machines, crane machines, bending machines, tracker machines and cutting machines. Their operation significantly slows down the shipbuilding process, but they are still preferred due to the high cost of buying automatic machines. Such investments, however, can speed up future production.

4.1.4.4 Method. In the method factor, there are two problems that impact the high production cost of shipbuilding, which are as follows.

*4.1.4.4.1 Long production process.* The production process for traditional wooden ships is long due to its manual, non-automatic nature. Furthermore, the longer the time spent on production, the more resources the company must spend on labor, which is compounded by company regulations preventing workers from switching teams or being replaced in each shipbuilding project. If any worker falls ill or takes leave, regardless of the ship size, the team of 5–7 must continue with fewer workers until the missing worker returns. Thus, the static nature of each team causes ships to take even longer to complete, which consumes more time and resources.

*4.1.4.4.2 Rework.* Rework is sometimes required due to the manual method used in shipbuilding, such as bending the wood by burning it with fire, and hull assembly by hitting the wood. Those processes can break the wood, creating rework requirements.

4.1.4.5 Measurement. In the measurement factor, two problems impact high shipbuilding production costs, which are as follows.

*4.1.4.5.1 The amount of woodcutting was not accurate.* The workers in traditional shipbuilding do not have any standardized method for measuring their work. For example, when a worker cuts a piece of wood, he or she does not record the measurement of the wood. Therefore, it is difficult to know how much wood was cut. Furthermore, material wastage is a common problem. When too much wood is cut for the ship, the workers set aside the extra wood, which clutters the work area.

*4.1.4.5.2 The result of wood bending is not optimal.* The traditional shipbuilding process is done by burning the wood and manually bending it, which can be a lengthy and unstandardized process. The manual work might not always be done correctly or with the required skill, meaning that the wood might be damaged and wasted.

4.1.4.6 Environment. In the environment factor, the problems that impact high production ship production costs are natural factors caused by rain and rocky land conditions. First, the rain can cause the production process to stop because the shipbuilding does not have a production place with a roof. Halted production will make the process take longer than planned. Second, the rocky terrain can damage the hull of the ship when it is launched.

Based on the results of interviews with experts, some of the root causes that have a dominant influence on the high cost of ship production include the long production process, different worker abilities and the wood being prone to damage. Several improvements proposed to decrease high production costs are summarized in Table 10.

Based on Table 10, there are several improvements proposed by the authors. Firstly, a long production process could be solved by updating the machines used in the production process, such as automatic cutting machines, tracker machines, wood dryer machines, crane machines, and wood bending machines, with automatic variants. Long production processes could happen because the process is still done manually. Manual or traditional processes need more workers and longer time in the ship production, so it can make the wages higher. Updating the traditional production process into machines could reduce labor, speed up the production time and reduce rework. This proposed improvement is in line with Oliveira and

| No | Root causes | Proposed improvement | Expected benefits |
|---|---|---|---|
| 1 | Long production process | Update machines used in the production process to become more automatic | Updating the machine used in production could speed up the process. As a result, a significant reduction of ship production time is achieved |
| 2 | Different worker ability | Change the combination of workers to be more ideal | Ideal combination of workers could reach the high performance. As a result, the production time can be faster |
| | | Provide regular training to the workers | Skilled workers have good performances, so the production time will be faster. As a result, the wages of the worker could be reduced |
| 3 | The wood prone to damage | Make standard operational procedures regarding the ways to handle different types of wood | Wood damage due to handling errors can be eliminated. As a result, the material cost can be reduced |

**Table 10.** Proposed improvements

Gordo (2018), who explain in their research that rework could be reduced by implementing more accurate technology.

Secondly, different worker abilities could be solved by changing the combination of workers in ideal numbers and providing regular training to the workers. Shipbuilding workers are classified into the beginner, medium and expert categories. However, different types of workers surely have different performances. It was observed that including a single expert in a team with lower-skilled personnel was insufficient. For this reason, a proposal was made to determine and implement the ideal combination of workers in order to increase productivity and decrease time spent on shipbuilding. This proposed improvement is in line with the study of Praharsi *et al.* (2019a) which analyzed the optimum number of workers that produced the lowest cost in traditional shipbuilding. The results from their study concluded that two expert workers per team provided lower labor costs with any combination of beginner and medium workers. This study proposed to the shipbuilding manager to use two experts rather than one expert per team in ship production. Besides that, to overcome different worker abilities, stakeholders could provide training to increase worker skill.

Finally, the wood prone to damage could be solved by making standard operational handling procedures. Standardized work contains a detailed, documented and visual system which the workers could follow (Singh, 2010; Sharma and Gandhi, 2017). By making standard operational procedures, the workers could understand the way to handle different types of wood to avoid errors in handling that impact on wood damage. This proposed improvement is supported by Sharma and Gandhi (2017) who studied lean principles and practices in shipbuilding. The result of their study was that standardized work can improve productivity by at least 45% gradually in shipbuilding. Wang *et al.* (2021) also explained that if standard operational procedure was established, then the improvement could continue.

*4.2 Supply chain performance of entire supplier*

Supplier performance measurement in the supply chain is divided into two parts: entire supplier performance and performance based on supplied materials. As mentioned in Table 11, the qualification of performance score is divided into three: parity, advantage and superior. The superior level is the highest (best) performance, advantage an intermediate or good level and parity a fairly good performance level.

*Entire performance supplier*. A supply chain comprises the whole process of activities involved in distributing products to the final consumer (Apriyani *et al.*, 2018). These activities involve the flow of goods, cash and information. Furthermore, supplier performance can be divided into two sections: external performance and internal performance. The results of the entire supplier performance measurement compared with the benchmark scores are shown in Table 11.

*External performance*. Reliability attribute scores measured by three metrics based on Table 11 explain that the supplier delivery performance gains a score of 94%. This means that supplier delivery performance is still at the advantage level, because of the inability of the suppliers to overcome the orders. Thus, the orders accumulate and tend to delay in delivery. As for the order fulfillment performance assessment, suppliers gained a score of 94%. It means that the performance of fulfillment by suppliers in the position of parity is caused by the low ability of suppliers to meet the orders of the shipbuilding industry. The perfect order fulfillment performance gained a score of 95%. This means that the suitability of the products produced by the standard suppliers according to customer's wishes obtained the superior category. In Table 11, the attributes of supplier flexibility gain a score of 2 days. This means that the supplier's ability to adapt with order changes by the shipbuilding industry has been very good or superior. Supplier responsiveness attribute scores measured through order fulfillment lead time obtained a score of 10 days. The supplier cannot fulfill the

| SCM attributes | Indicator | Parity | Benchmark Advantage | Superior | Score | Category |
|---|---|---|---|---|---|---|
| *External performance* | | | | | | |
| Reliability | Delivery performance (%) | 85–89 | 90–94 | ≥95 | 94 | Advantage |
| | Order fulfillment performance (%) | 94–95 | 96–97 | ≥98 | 94 | Parity |
| | Perfect order fulfillment (%) | 80–84 | 85–89 | ≥90 | 95 | Superior |
| Flexibility | Flexibility (days) | 30–26 | 25–21 | ≤20 | 2 | Superior |
| Responsiveness | Order fulfillment lead time (days) | 7–6 | 5–4 | ≤3 | 10 | Slightly parity |
| | Order fulfillment cycle time (days) | 8–7 | 6–5 | ≤4 | 6 | Advantage |
| *Internal performance* | | | | | | |
| Asset | Cash to cash cycle time (days) | 80–47 | 46–29 | ≤28 | 78 | Parity |
| | Inventory days of supply (days) | 39–55 | 23–38 | ≤22 | 67 | Slightly parity |
| | Asset turn | 8–11 | 12–18 | ≥19 | 49 | Superior |
| Cost | Cost of goods (%) | ≥64.08 | 51.5–64.07 | 26.54–51.4 | 78 | Parity |
| | Total supply chain cost (%) | 13–9 | 8–4 | ≤3 | 1.2 | Superior |

**Table 11.** Measurement performance score of the entire supplier

orders from the customer in fewer than 3 days due to insufficient inventory, after which point suppliers must wait from the manufacturer. For the order fulfillment cycle, suppliers gained the score of 6 days. It means that suppliers in the advantage category if the order fulfillment cycle without delay able to achieve in four days.

*Internal performance*. According to Bolstorff and Rosenbaum (2003), the whole supply chain's internal supplier performance can be measured in two attributes: assets and cost. The cash to cash cycle time score from suppliers in Table 11 is 78 days in the parity category. It means that suppliers have quite a long period in receiving payment from customers and stocking materials at the warehouse. Similarly, the score of inventory days of supply, which was 67 days, is classified in the slight parity category. For asset turnover, the average supplier score was 49 and classified in the superior category. This means that asset utilization on the production is very good and exceeded a score of 19. This should be communicated to the suppliers. For the cost attribute, the cost of goods is 78% and in the category of parity which means that suppliers have a lower profit margin. Therefore, evaluation of the policy is necessary to make the lean production process and increase more added values. For the total cost of supply, suppliers gained a score of 1.2% and were classified in the superior category which meant that suppliers were managing costs appropriately.

### *4.3 Each performance of wooden shipbuilding industry suppliers*

Besides the entire supplier performance measurement, we also carry out each supplier's performance measurement. Different product characteristics may cause differences in determining the supply chain performance measurement indicators (Apriyani *et al.*, 2018). So, the measurement of each supplier based on the goods supplied to the shipbuilding industry is carried out to see the supplier with the best performance and the worst. Each supplier's performance measurements were divided into two: external performance and internal performance. The results of the comparison score SCOR performance attributes with benchmark scores are presented in Table 12.

**Table 12.** Measurement performance score of each supplier

| SCM attributes | Indicator | Benchmark | | | Suppliers | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Parity | Advantage | Superior | Machine | Welding | Wood | Stainless steel | Bolts and nuts |
| *External performance* | | | | | | | | | |
| Reliability | Delivery performance (%) | 85–89 | 90–94 | ≥95 | 90 | 80 | 100 | 100 | – |
| | Order fulfillment performance (%) | 94–95 | 96–97 | ≥98 | 90 | 80 | 100 | 100 | 100 |
| | Perfect order fulfillment (%) | 80–84 | 85–89 | ≥90 | 95 | 95 | 95 | 95 | 95 |
| Flexibility | Flexibility (days) | 30–26 | 25–21 | ≤20 | 3 | 5 | 1 | 0.042 | 0.5 |
| Responsiveness | Order fulfillment lead time (days) | 7–6 | 5–4 | ≤3 | 17 | 15 | 1 | 7.5 | 7.1 |
| | Order fulfillment cycle time (days) | 8–7 | 6–5 | ≤4 | 14 | 12 | 1 | 0.292 | 0.08 |
| *Internal performance* | | | | | | | | | |
| Asset | Cash to cash cycle time (days) | 80–47 | 46–29 | ≤28 | 52 | 35 | 128 | 97 | 77.8 |
| | Inventory days of supply (days) | 39–55 | 23–38 | ≤22 | 36 | 21 | 115 | 84 | 77.8 |
| | Asset turn | 8–11 | 12–18 | ≥19 | 37 | 35 | 26.7 | 73.8 | 73.8 |
| Cost | Cost of goods (%) | ≥64.08 | 51.5–64.07 | 26.54–51.4 | 91 | 70 | 81 | 77 | 73 |
| | Total supply chain cost (%) | 13–9 | 8–4 | ≤3 | 1 | 0.67 | 1.5 | 2 | 1 |

*External performance*. External performance of each supplier is measured through the attributes of reliability, flexibility, and responsiveness. Attributes reliability can show which suppliers will be able to meet the orders of the shipbuilding industry on demand. In Table 12, the highest score of supplier delivery performance is wood supplier and supplier of stainless steel (100%), and the lowest is the supplier of welding (80%). Meanwhile, the bolts and nuts suppliers cannot be rated because they do not give shipping services at the shipbuilding industry. Meanwhile, the highest score of order fulfillment performance includes suppliers of wood, suppliers of stainless steel, nut and bolt supplier by score (100%), while the lowest score is the supplier of welding (80%). The excellence score of perfect order fulfillment attributes was reached by all suppliers (95%). It proves that the suppliers in the shipbuilding industry can deliver the goods per the wishes of the shipbuilding industry. The flexibility attribute reflects the ability of suppliers to respond to order changes given by the shipbuilding industry. The score of flexibility is the ability of the system to reach its target (Apriyani *et al.*, 2018). Flexibility in this study is presented in the form of "days." Table 12 shows that each supplier has achieved a superior position with flexibility under the 20-day period, yet the highest performance grade belongs to the stainless steel suppliers with a flexibility of 0.042 days or 1 h. Responsiveness is the ability of each supplier to fill orders as measured using order fulfillment lead times and order fulfillment cycles. In Table 12, the best score of order fulfillment is achieved by suppliers of wood with one day lead time. The supplier has a high wooden log inventory in order to avoid the rapid price increase and dry the log naturally, which needs at least 3 months. Meanwhile, the best score of order fulfillment cycle time is achieved by suppliers of stainless steel with the fastest order fulfillment cycle time of 0.292 days, equivalent to 7 h. Moreover, welding suppliers have the lowest order fulfillment lead time and cycle time because their work systems are not in order. As a result, the orders of the customers are postponed.

*Internal performance*. Internal performance of each supplier is measured through asset attributes and cost. For asset attributes, performance assessment is measured through three metrics: cash to cash cycle time, inventory days of supply and asset turn. In Table 12, it can be seen that the lowest cash to cash cycle time is at the supplier of welding machine of 35 days in advantage level. The main cause is a credit system between the owners of the shipbuilding industry to the suppliers. For the inventory days of supply, the welding supplier is at the superior level and the machine supplier is at the parity level. The longest inventory days of supply were of the wood supplier. Furthermore, the asset matrix turn is the supplier's ability to optimize the assets to get revenue as much as possible. Based on Table 12, the asset turn score is best achieved by stainless steel and bolts and nuts suppliers with a turnover of 73.8 times per year. Yet, all suppliers are at superior levels which reached larger than 19 times. Cost attributes measure two performance assessment metrics: the cost of goods and the total supply chain cost. The cost of goods is direct costs for the material and wage costs required to make the product. In Table 12, the best score of the cost of goods is the supplier of welding with a score 70%, but these scores are still in the position of parity. This is because of the lack of good financial management to reduce material and labor costs while gaining more profits. The total cost of the supply chain cost is the cost incurred for the product to the customer. Table 12 shows that the best score of the total supply chain cost attribute is in all suppliers, with the largest score of 2% at the superior level. This proves that all suppliers can manage supply chain financing costs well.

## 5. Implications

This study offers two types of implications: theoretical and practical. Theoretically, the research contributes to the literature using a real case application of the SCOR model to measure the supply chain performance of an ETO project for a traditional shipbuilding industry. We have discovered that not every metric within the SCOR model is applicable for shipbuilding performance measurement. Therefore, this study proposed two new metrics, (right product and right condition, and right time) to enable shipbuilding industries to achieve their maximum performance and customer satisfaction. The new metrics developed in this research can also be adapted for implementing the SCOR model to measure the supply chain performance in other similar and ETO industries.

In practical terms, the implementation of these proposed SCOR metrics will help companies to better understand their internal and external performance. The internal performance tool is related to cost and assets, while the external performance is measured in reliability, flexibility and responsiveness. As a result, companies can analyze both the strongest and weakest aspects of their own performance. The weakest performance measurement among others is the COGS, because the company spends too much operational cost to build a boat. To remedy this situation, the authors have proposed some specific improvement steps to be implemented by the company to decrease its costs. Thus, in the next project, the shipbuilding industry's owners can decide the right steps to sustain, improve or even reform their supply chain process to gain higher profit. Not only can these performance measurements be used for the traditional shipbuilding industry, but they can also be provided also can be provided as a replicable benchmark to other types of global shipbuilding industries, including steel ships and warships, for their continuous performance improvement.

## 6. Conclusion

This study has explored the supply chain performance of the traditional shipbuilding industry in Indonesia, and measured the performance based on its internal and external supply chain. Five metrics are used to measure internal supply chain performance. They are cash to cash cycle time, inventory days of supply, asset turn, cost of goods and the total supply chain cost. The delivery performance, order fulfillment performance, perfect order fulfillment, flexibility, order fulfillment lead time and order fulfillment cycle time are the metrics for external supply chain performance. There are three main parts of the performance results in this research study. They are the traditional shipbuilding industry, the suppliers, and the score of each supplier.

Optimal traditional shipbuilding industry performance can be measured under perfect order fulfillment, flexibility, asset turn, and total supply chain cost. Perfect order fulfillment can be achieved by monitoring and controlling customers in each stage of the manufacturing process. Traditional shipbuilding industries are flexible with order changes because most of the workers have more than 10 years of experience. This 1-month flexibility applies to each manufacturing process stage except for the hull construction. A barrier for delivering on time is the uncertain leave of workers during sea trials. Another barrier is due to the "no contract agreement" with the customers. In traditional shipbuilding industries, there are no penalties charged for late delivery. Further performance improvements of the traditional shipbuilding industries are the cost of goods sales and order fulfillment performance. Some ways to improve these performances include modernizing the tools to scale up production size, improve the flow of raw materials and systematic training of workers. As suggested by Praharsi *et al.* (2019a), optimizing the number of workers can also minimize the total cost. The SCOR metrics that cannot be implemented in traditional shipbuilding industry performance measurement are order fulfillment lead time, order fulfillment cycle time, cash to cash cycle time and supply inventory days. Order fulfillment lead time and cycle time cannot be determined because they depend on the manufacturing time which varies according to the boats, GT sizes. Moreover, traditional shipbuilding industries do not have supply inventory days because their production system is based on engineering to order. The company will design and manufacture the ships only after customer orders. Thus, cash to cash cycle time cannot be determined as well.

The optimal supplier performance metrics include order fulfillment, flexibility, asset turn and total supply chain costs. In the study, wood suppliers and stainless steel suppliers are superior in terms of delivery performance, order fulfillment and order fulfillment cycle time. In general, an integrated synchronized ordering system with the suppliers is necessary to improve performance. Other lean production processes (Praharsi *et al.*, 2019b) and six sigma approaches (Praharsi *et al.*, 2020) can be implemented to boost supplier performance. For future research, more indicators can be developed to measure the performance of the traditional ETO shipbuilding industries.

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