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The application of Lean Six Sigma and supply chain resilience in maritime industry during the era of COVID-19

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Abstract

Purpose – This study aims to apply a Lean Six Sigma framework to support continuous improvement in the maritime industry (shipbuilding, logistics services and shipping companies) during COVID-19 pandemics. By applying the concepts of Lean Six Sigma and supply chain resilience, the most suitable continuous improvement method for the maritime industry is developed to maintain a resilient supply chain during COVID-19.

Design/methodology/approach – A specific shipbuilding, logistics services and shipping company in Indonesia is chosen as the research object. The Lean Six Sigma framework reveals the wastes through the supply chain resilience concept, and implements internal business processes to maintain optimal system performance.

Findings – The paper identifies important implementation aspects in applying Lean Six Sigma to shipbuilding, logistics services and shipping. The DMAIC (define, measure, analyze, improve and control) approach is applied to achieve supply chain resilience. Resilient measures are generated for the case companies to maximize performance during the pandemics.

Practical implications – This paper provides a new insight for integrating Lean Six Sigma and resilience strategies in the maritime industry during COVID-19 disruptions. The authors provide some insights to sustain the performance of the maritime industries under study.

Originality/value – This study is part of the first research in the maritime industry that focuses on continuous improvement during COVID-19 using Lean Six Sigma and supply chain resilience.

Keywords Lean Six Sigma, Supply chain resilience, Continuous improvement, Maritime industry, COVID-19

Paper type Case study

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1. Introduction

In supply chain activities, logistics plays an important role in the distribution of goods from producers to consumers. Assessing the performance of a supply chain depends on logistics quality services and cost. During the COVID-19 pandemic in 2020, the traditional shipbuilding industries in Indonesia experienced a decrease in production and service quality because of large-scale social restrictions which have affected material supply chain activities and production delays. Therefore, traditional shipbuilding needs a drastic improvement to deal with the crisis. This motivates our research.

One activity in Indonesian goods delivery services affected by COVID-19 is the store-to-store (STS) business process, which sends goods from one store to another. Some of the obstacles are deliveries, order number mismatches and decreasing number of orders. Because of the pandemics, there was a drastic decline in orders from April to June 2020. This drastic decline rate was influenced by the existence of strict lockdown regulations in Indonesia.

In addition to the traditional shipbuilding industry and logistics companies, shipping companies were also affected by the COVID-19 pandemics. Several studies have described efforts to eliminate waste or non-value-added activities with Lean Six Sigma (LSS). Ruiz-benitez *et al.* (2018) examined the relationship between LSS and supply chain resilience (SCR) and the impact on supply chain performance. Lohmer *et al.* (2020) examined the application of technology and its impact on the supply chain. Further research conducted by Rajesh (2017) examined the technological capabilities of companies that contribute to SCR. Later, Rajesh (2019) analyzed the efforts in increasing SCR capacity in a company.

SCR has gained more attention recently among researchers, especially during the COVID-19 pandemic. Golan *et al.* (2020) investigated the trends and applications of resilience analytics of supply chain during COVID-19. They explained that in the pandemic, modeling supply chains should not only focus on the recovery stage, but also the earlier stages. Furthermore, SCR in maritime industry should focus on two perspectives: principal customer requirements and risk factors from the supply chain's point of view (Lam and Bai, 2016). The concept of SCR emerges as a solution in solving problems caused by external, internal or natural disturbances. Supply chain disruption arises from a combination of an unwanted and unexpected triggering event occurring somewhere in the upstream supply chain (supply network), incoming logistics network or environmental purchasing, and consequential situations, which present a serious threat to the normal business activity (Bode and McDonald, 2017).

The relationship between SCR and the performance of a shipping industry was examined by Liu *et al.* (2018). Garza-Reyes *et al.* (2016a, 2016b) proposed a framework to effectively deploy LSS and improved the key operation and performance indicators to reduce commercial ship loading times. Abdul Rahman *et al.* (2019) used the analytical hierarchy process method to determine the most significant delay factor in the operation of dry bulk carriers. Lam and Bai (2016) proposed several efforts to improve maritime SCR with the quality function deployment (QFD) approach.

Previous studies were limited for not having considered the effect of the COVID-19 pandemics. This research achieves the following objectives:

- to understand the benefits and challenges of implementing the LSS during the COVID-19 pandemics for the maritime industry (shipbuilding, logistics services and shipping companies); and
- to propose suitable resilience measures to the maritime industry, thus achieving SCR during the pandemics.

The rest of the paper is organized as follows. The literature review is presented in Section 2. Section 3 discusses the research methodology. Section 4 describes the implementation of LSS using define, measure, analyze, improvement and control stages. Finally, Section 5 presents conclusions, limitations and direction for future research.

2. Literature review

2.1 Lean Six Sigma

The Lean concept is one of the most widely used methodologies for process improvement. It is divided into two functions based on the industry types, which are "Lean manufacturing" and "Lean service." Lean manufacturing consists of seven wastes (transport, inventory, motion, waiting, overproduction, over-processing and defects); it was introduced by Taiichi Ohno (1988). Lean service consists of eight wastes (overproduction, delay, un-needed transport/movement, over-quality/duplication, lack of standardization, failure demand/miscommunication, underused resources and manager's resistance to change); it was proposed by Andrés-lópez *et al.*, (2015). In this paper, Lean service is used to assess the performance of shipping and logistic companies. However, the shipbuilding industry also uses the Lean manufacturing concept to identify the types of wastes (Praharsi *et al.*, 2019a, 2019b).

The main objectives of Six Sigma are to make improvements, standarization and proposals for business process improvements, so that companies can increase profit, sustainability and provide satisfaction or added value to customers. Six Sigma applies the DMAIC phase (define, measure, analyze, improve and control) for its cycle improvement. (Gutierrez-Gutierrez *et al.*, 2016).

LSS has gained popularity and acceptance as an integrated framework (Antony *et al.*, 2017). LSS has been successfully applied in individual organizations in both manufacturing and service contexts such as the auto industry, education, electronics, construction, software development, call centers, health care and logistics services (Albliwi *et al.*, 2014). LSS is defined as a long-term decision-making strategy which minimizes variation in quality and process, maximizes value-added content and improves customer satisfaction (Singh and Rathi, 2019). The additional advantages include quality and productivity improvement, and more effective and efficient supply chain (Chiarini, 2011). Some researchers and experts affirmed LSS as one of the most suitable continuous improvement tools for supply chain management (Knowles, 2005) (Salah, 2011). This study differs from previous studies in three ways. First, the research integrates LSS principles and resilience practice. Second, resilience practices are implemented in Six Sigma continuous improvement based on resilience criteria, making the companies more sustainable. Finally, the study involved a maritime industry case, which includes shipbuilding, liner shipping and logistic companies.

2.1.1 Lean Six Sigma in shipbuilding industry. From the Emerald, ScienceDirect and Taylor Francis databases from 2011 to 2020, literature related to shipbuilding and LSS was explored. The previous research on the application of LSS in shipbuilding industry is summarized in Table 1.

2.1.2 Lean Six Sigma in logistics service industry. LSS applications in logistics service industry have improved company operational performance through continuous improvement (Abdallah, 2020). Recently, many third-party logistics companies in East Java, Indonesia, are concerned about logistics service performance (Sumantri, 2019). Zhang *et al.* (2016) showed that most logistics companies in Singapore did not implement LSS in their business processes. In the past decade (2011–2020), very few studies discussed the application of LSS in a logistics service industry, specifically for third-party logistics and multimodal transport (Zhang *et al.*, 2016). The previous research on the logistics industry is summarized in Table 2.

No.	Authors (year)	Object of the research	Variable used	Result
1.	Marcos *et al.* (2020)	Case study on Estaleiro Atlantico Sul (EAS) shipyard	Lean manufacturing	The author suggested the implementation of lean manufacturing in the Estaleiro Atlantico Sul (EAS) shipyard. They found that contextualization factors have impacted the implementation of lean manufacturing in the shipbuilding industry
2.	De Moura and Botter (2017)	Toyota Production System, Shipyards in Brazil	Lean production, Agility	The study implemented the Toyota Production System for shipyards in Brazil The study used the same standard work process method as the one used in the automobile industry. The Lean approach reduced wastes and improved productivivity
3.	Besseris (2011)	Case study, Maritime transport	Maritime transport, Lean production, Six Sigma	The author implemented design of experiment using LSS. The application of LSS in maritime operations reduced international tariffs and improved environmental awareness and energy consumption

Table 1.
Previous studies of LSS in shipbuilding industry

2.1.3 Lean Six Sigma in shipping industry. LSS-related studies in the shipping industry are relatively new. Garza-reyes *et al.* (2016a, 2016b) developed an LSS approach to reduce commercial loading time of iron ore transport ships. Their research effectively implements LSS in company and contributes to improving both capability of operational process and financial. Gutierrez-Gutierrez *et al.* (2016) explained essential strategic analysis, cross-functional teams, improvement tools and process management in implementation of LSS in logistic service. Moreover, LSS implementation in that study showed significant improvement for the company. Besseris (2011) studied maritime operations. To boost efficiency, an LSS project was conducted for dry bulk carrier marine engines. DOE Toolkit and LSS methods are used to improve efficiency in vessel speed, exhaust gas temperature and fuel consumption. However, there are no previous studies that examined LSS in the shipping industry. Previous research of LSS in shipping industry are summarized in Table 3.

2.2 Supply chain resilience

2.2.1 Supply chain resilience in shipbuilding industry. The principles used in SCR include SC re-engineering, SC collaboration, agility and SCRM culture. Some of the studies that addressed resilient supply chain in maritime industry are those of de Moura and Botter (2017), Ramirez-Peña *et al.* (2019) and Kamalahmadi and Parast (2016). Kamalahmadi and Parast (2016) proposed three specific resilience attributes. The first set of attributes includes flexibility and redundancy. Flexibility is defined as the ability to respond and recover from abnormal situations. Redundancy includes multiple suppliers, safety stock, excess capacity and backup suppliers. The second set of attributes includes resilience, trust, information sharing and collaboration. Mutual buyer–supplier trust can create greater relational resilience between buyer–supplier relationships, and collaboration occurs when each member receives the relevant information sharing efficiently and effectively. The third set of

No.	Authors (year)	Object of the research	Variable used	Result
1	Abdallah (2020)	E-commerce logistics	Labor, work in process (WIP) and time packages	The proposed project had reduced the labor size by 65%, WIP by 41% and the average time packages spent at the station by 55%
2	Pozo *et al.* (2020)	Multimodal transport	Process time and inventory costs	Reduced common critical path mapping process time in port and the inventory costs using the railroad
3	Sumantri (2019)	Third-party logistics	Problem-solving, process and long-term philosophy	Most third-party logistics companies in East Java prioritized the process to achieve total quality performance
4	Garza-Reyes *et al.* (2016)	Transport and logistics	Operational efficiency and environmental performance	The proposed sustainable transportation value stream map (STVSM) tool was shown to be an effective approach to improve operational efficiency and environmental performance
5	Zhang *et al.* (2016)	Logistics	Implementation	The first research in applying LSS in logistics. The implementation rate among large firms was much higher
6	Jayaram (2016)	Global supply chain	Autonomy, optimization, visualization and connectivity	The GSCM model implemented connectivity, optimization and visualization. It reduced costs and optimized the overall performance
7	Pejić *et al.* (2016)	Logistics	Lean logistics, Green Logistics	Few papers considering both Green and Lean logistics in manufacturing industries
8	Antunes *et al.* (2013)	Logistics	Supply delays, supply failures and supply errors	Supply delays, supply failures and supply error were the three factors to support performance improvement

Table 2.
Previous studies of LSS in logistic service industry

No.	Authors (year)	Object of the research	Variable used	Result
1.	Garza-reyes *et al.* (2016)	Ship loading in the iron ore pelletizing industry	Commercial time	Improved commercial time in both process capability index and loading commercial time by more than 30%, allowing the organization to save US$300,000 per annum
2.	Gutierrez-Gutierrez *et al.* (2016)	Transportation	Payment process and request-to-ship process	The essential aspects to consider when applying LSS in logistics services are strategic analysis, cross-functional teams, improvement tools and process management which significantly improve operations
3.	Besseris (2011)	Marine engines of a double-skin bulk carrier	1. Vessel speed (VS) 2. Exhaust gas temperature (EGT) 3. Fuel consumption (FC)	The desirability value for VS, EGT and FC was obtained at levels over 0.90

Table 3.
Previous studies of LSS in shipping industry

attributes includes resilience and agility (visibility and velocity). Visibility is a knowledge or information source for the environment between customers and suppliers. Velocity is closely related to flexibility and adaptability, and reflects the speed of information exchange.

Rajesh (2017) stated that technological capabilities involvement can increase the resilience of a supply chain. Rajesh (2019) showed that aligning tasks awareness among employees is an important indicator SCR. The previous research related to SCR and shipbuilding, or LSS, SCR and shipbuilding is listed in Tables 4 and Table 5.

2.2.2 Supply chain resilience in logistics service industry. Kamalahmadi and Parast (2016) stated that resilience is a multidimensional and multidisciplinary concept, whereas Ambulkar *et al.* (2015) defined resilience as a supply chain's recovery capability to disruptions. Resilience is conceived to consist of two keys components, namely, resistance and recovery capacity (Asamoah *et al.*, 2020). Hosseini *et al.* (2019) showed that the SCR concept consists of agility, robustness, visibility, flexibility, collaboration and information sharing. Table 6 lists several literature examples on SCR for service companies.

No.	Authors (year)	Object of the research	Resilience strategies	Result
1.	Al-Talib *et al.* (2020)	Literature review	Supply chain resilience, IoT (Internet of Things)	A framework for supply chain resilience is developed based on IoT technologies. The SC redesign framework can reinforce supply chain flexibility and improve their SCR
2.	Singh *et al.* (2019)	Literature review	Performance indicators for supply chain resilience, supply chain resilience framework	Supply chain resilience is composed of three phases, and each phase contains performance indicators at supply chain resilience framework. The supply chain resilience framework is developed to check and prevent interruption, thus improving the resilient performance of a supply chain
3.	Rajesh (2017)	Literature review	Supply chain resilience, Technology capability	From the study, it was concluded that technology capabilities affect supply chain design and planning capabilities. Appropriate enhancement of the supply chain capacity can increase flexibility and improve resilience
4.	Kamalahmadi and Parast (2016)	Literature review	Supply chain resilience, supply chain resilience framework	Developed frameworks can be used to understand supply chain resilience. The principles of supply chain resilience are SC re-engineering, collaboration, agility and SCRM culture
5.	Tukamuhabwa *et al.* (2015)	Literature review	Supply chain resilience, complex adaptive system	Strategies used to increase resilience which focus on increasing flexibility to changing environmental require time and effort. Forming collaborative SCM relationships can forge mutually beneficial cooperation and increase supply chain agility

Table 4. Previous studies of SCR in shipbuilding industry

No.	Authors (year)	Object of the research	Variable used	Result
1.	Ramirez-Peña *et al.* (2019)	Shipbuilding	Technology I4.0; Green; Lean; Agile; Resilient	Shipbuilding supply chain paradigms associated with I4.0 technology are Lean, Agile, Resilience and Green. Green and Lean paradigms are defined as the most influencing global performance. In this way, total visibility and connectivity required on Shipbuilding Supply Chain 4.0 could be achieved
2.	Mensah and Merkuryev (2014)	Literature review	Lean production, Six Sigma strategy, SC flexibility and corporate culture	The author proposed four strategies, namely, Lean production, Six Sigma strategy, flexibility and corporate culture. The focus is to implement Lean production (awareness, quality assurance, level production, just in time) and the six sigma strategy as an alternative. Both of these strategies could be supported by flexibility and corporate culture

Table 5.
Previous studies of SCR and LSS in shipbuilding industry

This paper implements two dimensions suitable to the logistics service, which are "agility" and "robustness." Agility is related to dexterity in terms of handling risks that may occur during the service process, whereas robustness is associated as defense activities that can be carried out by the company to maintain the overall level of service quality. Further details of every attribute used can be seen in Section 4.

2.2.3 Supply chain resilience in shipping industry. Disruptions, whether natural or human-caused, are an inherent part of the global context of all supply chains (Golan *et al.*, 2020). Shipping company operation is complicated and fragile (Liu *et al.*, 2018). The operational challenges in the industry related to unstable economic cycles, empty container repositioning, seafarer shortages, escalating bunker prices, cargo space oversupply, fluctuating ship prices and port closures (Liu *et al.*, 2018). Mason and Nair (2013) explained about the challenges in container shipping service-related supply issues, demand challenges and regulatory changes. For the resilience measures improving maritime SCR, five measures are explained: contingency plan, forecast accuracy, strategic alliance, supply chain relationship management, advanced IT system, monitoring and maintenance (Carvalho *et al.*, 2012; Lam and Bai, 2016). Contingency plans are related to organizing skill-specific backup plans. Increasing the demand forecast accuracy can reduce the level of inventory and increase SC visibility and responsiveness. Strategic alliance establishes collaborative program, which reduces uncertainties (Lam and Bai, 2016) and maintains a good supply chain relationship. Moreover, advanced IT systems could be used for real-time tracking systems, monitoring and maintenance to ensure perform as expected (Lam and Bai, 2016).

Table 7 presents the studies related with SCR in shipping, transportation and logistics service. Liu *et al.* (2018) analyze the relationship between SCR and the firm's performance in the shipping industry. There was a positive effect of risk management culture on SCR variables (agility, integration and supply chain re-engineering). Lam and Bai (2016) developed a QFD approach to enhance maritime SCR in shipping liner companies. Ishfaq (2012) conducted research on multi-mode transportation networks; the result showed that multiple modes are better than the OTR (over-the-road) options. Implementing resilience

No.	Authors (Year)	Object of the research	Variable used	Result
1	Kayikci (2020)	Global Freight Transport	Robustness, redundancy, resourcefulness, maintenance, safe-to-fail, preparedness, collaboration, leadership and culture, skilled labor and management	Rapidity, preparedness, and maintenance had the highest value to impact environmental performance and resilience
2	Asamoah *et al.* (2020)	Service-based company	Collaboration	SMEs disruptions and uncertainties decreased through resilient social network relationships
3	Jeng (2018)	Logistics	Employee creativity	Creative behaviors of frontline employees had the potential impact on supply chain resiliency and logistics performance
4	Ali *et al.* (2018)	Cold chain logistics	Business certifications, multi-skilled workforce, quality management system, multi-sourcing, public–private collaboration and globalized operations	Cold chain logistics risks were reduced through the proposed resilience model
5	Liu and Lee (2018)	Third-party logistics	Internal integration, fustomer integration and logistics collaborator integration	Internal integration was considered to be the most effective in the SCR
6	Saraswati *et al.* (2017)	Freight forwarder	Cohesion, diversity, adaptability	Cohesion was chosen as the best dimension in improving the company's performance with the resilience measures
7	Mandal *et al.* (2017)	Logistics	Collaboration, flexibility, visibility, velocity	SC collaboration and visibility were chosen as the precursors for developing other SC capabilities
8	Jain *et al.* (2017)	Logistics	Adaptive capability, collaboration, trust, sustainability, risk and revenue sharing, information sharing, SC structure, technological capability	This paper identified 13 key enablers. Resilience can be enhanced using these 13 key SCR enablers
9	Lam and Bai (2016)	Shipping liner	Collaboration, flexibility and visibility	Contingency plan, monitoring and maintenance and supply chain relationship management were chosen as the best resilience measure
10	Bühler *et al.* (2016)	Logistics service	Flexibility, reliability	Performance measurement systems (PMS) design for accounting increased organizational resilience and distribution service performance

(*continued*)

Table 6.
Previous studies of SCR in logistics service industry

No.	Authors (Year)	Object of the research	Variable used	Result
11	Pettit *et al.* (2013)	Global retailing, MNC consumer electronics, medical transportation, global chemical, global manufacturing, MNC chemical	Flexibility in sourcing, flexibility in order fulfillment, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organization, market position, security, financial strength	Specific resilient measures were found to help the improvement process
12	Ishfaq (2012)	Multi-mode Logistics	Flexibility	By implementing flexibility in a proposed operational logistics strategy, multi-mode company had managed the effect of transportation disruptions

Table 6.

No.	Authors	Object	Variable	Result
1	Liu *et al.* (2018)	Taiwanese liner shipping industry	1. Risk management culture 2. Agility 3. Integration 4. Supply chain re-engineering	There are positive effects of risk management culture on agility, integration and supply chain re-engineering. Risk management is important to a firm performance
2	Lam and Bai (2016)	Top 20 shipping liner companies	1. Collaboration 2. Flexibility 3. Visibility 4. Supply chain risk	By developing QFD approach, the key findings were as follows: 1. The top three requirements are on-time and hassle-free shipment delivery, easy real-time shipment tracking and professional staff 2. The top three risks are IT system, operational risks and HRM risk 3. The top three resilience measures are contingency plan, monitoring and maintenance and supply chain relationship management
3	Ishfaq (2012)	US multi–mode transportation networks	Flexibility and efficiency	Considering cost and services in transportation disruption, the use of multiple modes is better than the use of OTR (over-the-road) options
4	Mason and Nair (2013)	Container liner shipping sector	Flexibility	Using a system methodology in managing supply chain flexibility to face uncertainties
5	Azadeh *et al.* (2014)	Transportation sector	1. Visibility 2. Velocity 3. Redundancy 4. Flexibility	The study concludes that implementing resilience factors in transportation could result in a better output and recommend the inclusion of visibility feature and redundancy as other resilient variables
6	Bhaskar *et al.* (2014)	Shipping companies	Sustainable	To be sustainable, shipping companies should be able to absorb shocks and adjust to changing environments

Table 7.
Previous studies of SCR in shipping industry

factors in transportation could bring better output, especially in visibility and redundancy resilience (Azadeh *et al.*, 2014). Mason and Nair (2013) explained flexibility tactics that could be deployed to make companies more resilient in the face of economic uncertainties. Bhaskar *et al.* (2014) proposed making shipping companies sustainable to absorb shocks and adjust to changing environments.

2.3 Shipbuilding, logistics service and shipping industry

Handmade wooden boats are a product of traditional shipbuilding in Indonesia, with techniques passed down by their ancestors (Praharsi *et al.*, 2019a, 2019b). This wooden boatbuilding technique is very different from modern shipbuilding practices. Service logistics has a different concept from logistics service. Service logistics focus on the interaction between consumers and companies (Gutierrez-Gutierrez *et al.*, 2016); whereas logistics service is an extension of physical distribution and information management within a distribution channel. Logistic activities in services include reducing the lead time and the evaluation of the procedures implemented. The service logistics business process consists of several types: one of them is the courier business process commonly referred as STS delivery. The delivery distance can be made between cities and provinces depending on the location of the pick-up shop and the destination store. Deliveries are made using cargo trucks with standard lead times.

Three parties relating to commercial shipping activities are shippers, carriers and consignees. Each of these has rights and obligations regulated by the national laws/government and several international conventions. Other important shipping industries are forwarders, warehousing, stevedoring and freight forwarders.

2.4 Pandemics

The COVID-19 pandemic has resulted in global supply chains disruptions of unprecedented scale. Resilience supply chains enable the supply chain to absorb, recover and adapt to disruptions effectively. This study can help future planning efforts to reduce the impact of supply chains disruptions.

3. Research methodology

From Figure 1, the research starts with collecting data from the traditional shipyards, logistics and shipping companies. The discussion with our focus group and brainstorming with the stakeholders regarding the collected data are carried out. The implementation of LSS is then described as follows:

- The seven wastes of manufacturing are identified. The waste in logistics and shipping industries are referred as service waste.
- The next stage determines the critical to quality (CTQ) for waste processing. The business process of each industry is defined.
- The defect per million opportunity (DPMO) and sigma values are calculated at this measurement stage.
- The root cause is analyzed using a fishbone diagram. Subsequently, the root cause is evaluated to determine the risk priority number (RPN) using the failure mode effect analysis (FMEA) method.
- The high values of RPN are recommended to propose improvements.

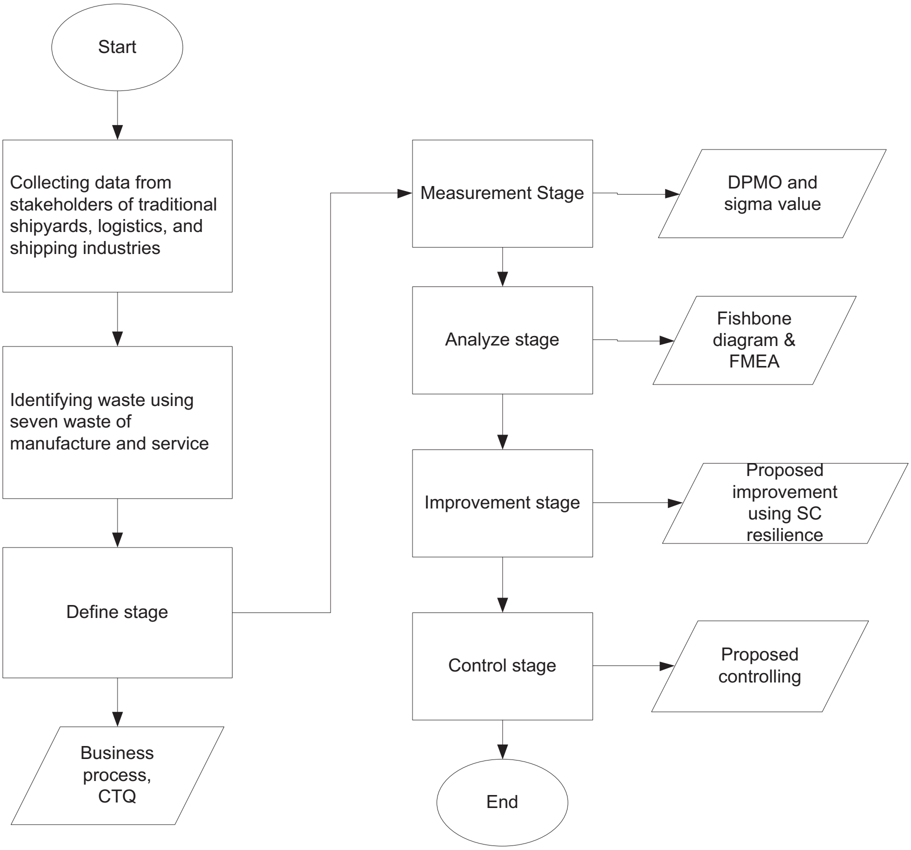

Figure 1.
Research method

The SCR strategies are integrated into the proposed improvements to consider the impact of Covid-19 pandemic. Finally, controlling actions are proposed for continuous improvement.

4. Results and discussions

4.1 Traditional shipbuilding industry

4.1.1 Define. Based on the interview with several owners of traditional shipbuilding companies, it is known that the COVID-19 pandemics have disrupted shipbuilding activities, resulting in a decline in ship production. Using the seven waste principal for manufacturing such as Transport, inventory, motion, waiting, over-processing, overproduction and defects (Putri and Dona, 2019; Praharsi *et al.*, 2019a, 2019b), non-value-added activities that interfere the shipbuilding process are identified in Table 8. The three shipyard owners identified four wastes categories, namely, inventory, waiting, over-processing and defects.

All of the wastes above are used as input in the fishbone diagram to find the root cause of the problem.

4.1.2 Analysis. In this analysis stage, we analyze the shipbuilding disruptions by using four waste classifications and several factors because of the COVID-19 pandemics.

4.1.3 Fishbones. Based on the results of interviews conducted with the three experts in the shipyard industry, the classification of waste and non-value-added activities is included in the fishbone diagram as shown in Figure 2.

Figure 2 illustrates the fishbone diagram as follows:

- Man

  Human factors affect shipbuilding in two areas; these include poor performance or suboptimal performance caused by worker's errors; and limited worker skill because of the lack of training.

- Machine

  The unsupported machines and technology may cause disruptions. The implementation of social distancing during the COVID-19 pandemic situation adds to the problem.

Four waste categories	Cause of wastes activities
Inventory	Wood storage failure in warehouse
Waiting	Shortage of experts for bending the wood
	Too many ships to build
	Raining
	Semi-manual wood cutting
	Limited space for sawmill processing
Over-processing	Over-processing work on deckhouse
Defects	Error of wood cutting
	Crack because of assembly
	Crack because of burning for wood bending
	Unstandarized method
	Wood shrinkage
	Human errors

Table 8. Classification of four waste and non-value-added activities (from the interview with the traditional shipbuilding companies)

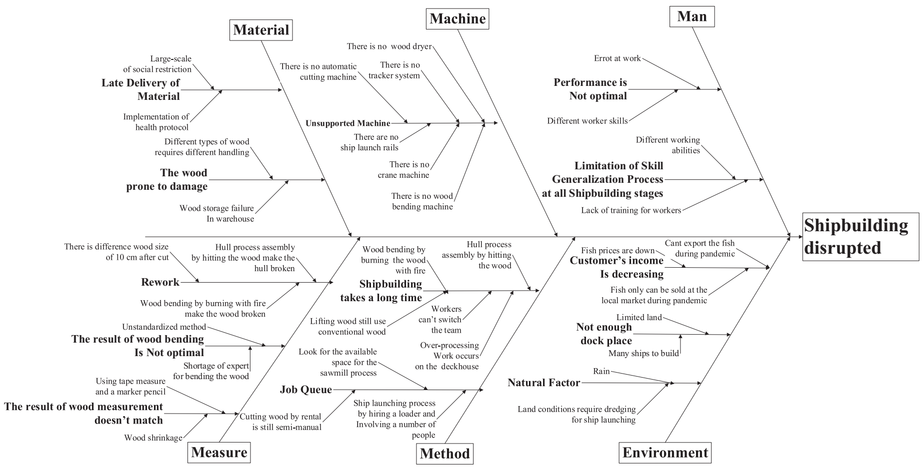

Figure 2. Fishbone analysis of shipbuilding

- Material

  Two problems that impact shipbuilding are delayed material delivery because of large-scale social restrictions and the implementations of health protocols during the COVID-19 pandemics; and failure of damage-prone wood during handling and storage.
- Measure

  The three problems that impact shipbuilding are rework after wrong cuts, lack of standardized methods and wood measurement mismatches caused by wood shrinkage.
- Method

  The two methods that impact shipbuilding are shipbuilding process and problem involving the queue of work caused by the ship-launching process.
- Environment

  The three environmental factors that impact shipbuilding are decreasing consumer income because of the falling fish prices, dock area shortages and natural factors because of rain and infrastructure.

Based on the results of the FMEA, the top 10 of the 36 criteria have been compiled from three respondents interview. The RPN average values are listed in Table 9.

The total RPN average value is obtained from the sum of the RPN value Resp. 1, RPN value Resp. 2 and RPN value Resp. 3. Then, the result of the sum is divided by 3, the number of respondents involved in determining the RPN value. Of the 36 causes, only 10 are taken with the total average value of RPN as shown in Table 9. The overall RPN value for each respondent can be seen in the Appendix.

4.1.4 Improvement. At this stage, the proposed improvements of activities in shipbuilding industry are presented in Table 10. The proposed improvements used are the results of studies from previous studies adjusted to shipbuilding industry.

Potential failure mode	Causes	RPN value Resp. 1	RPN value Resp. 2	RPN value Resp. 3	Total average value of RPN
Shipbuilding disrupted	There are no ship launch	27	392	567	328,667
	Raining	120	400	280	266,667
	There is no automatic cutting machine	125	84	567	258,667
	There is no tracker machine (removing boring)	125	84	567	258,667
	Lack of training for workers	200	384	125	236,333
	There is no wood dryer	75	21	567	221
	There is no crane machine	1	36	567	201,333
	There is no wood-bending machine yet	1	12	567	193,333
	Cutting wood by rental is still semi-manual	200	126	245	190,333
	The capabilities of each worker are different	200	168	147	171,667

Table 9.
FMEA Table

No.	Cause	Resilience strategies	Resilience attributes	Specific action for improvement
1.	There is no automatic cutting machine	SC re-engineering	Technological capability (Rajesh, 2017)	Purchase automatic wood-cutting machines for more standardized wood cut results because it can increase production flexibility and enchance resilience
2.	There is no trecker machine (removing boring)	SC re-engineering	Autonomous robots (Ramirez-Peña *et al.*, 2019)	Provide tracker machines/tools to increased efficiency and productivity, reduced errors, rework and risk rates, improved worker safety, improved customer satisfaction
3.	There is no wood dryer	Lean production	JIT delivery and low inventory (Mensah and Merkuryev, 2014)	Purchase oven or a wood-drying machine to minimize waste and inefficiency. Continuous improvement in quality, productivity and responsiveness
4.	There is no crane machine	SCRM culture	Increasing innovativeness (Tukamuhabwa *et al.*, 2015)	Purchase crane machine to lift wood from the bottom to the top of the shipbuilding to reduce vulnerability and prevent work accident
5.	There is no wood bending machine	Lean production	Agility (de Moura and Botter, 2017)	Purchase wood-bending machine to avoid damage to the wood so that the result can valuing the product and service
6.	Cutting wood by rental is still semi-manual	SC collaboration	Information sharing (Kamalahmadi and Parast, 2016)	Collaborating with partners; for example, cutting services for wood, to schedule and post information in real time using the application
7.	There are no ship launch rails	SCRM culture	Disruptions conditioning (Rajesh, 2019)	Applying the use of rails at ship launching to avoid hull damage
8.	Raining	SC re-engineering	Redundancy (Kamalahmadi and Parast, 2016)	Install a roof (indoor) so the production process will not be afffected by rain
9.	The abilities of each worker are different	SCRM culture	Aligning task (Rajesh, 2019)	Providing guidelines or SOPs that are easily understood by each worker
10.	Lack of training for workers	SCRM culture	Leadership (Kamalahmadi and Parast, 2016)	Providing appropriate training for the worker to improve their skills

Table 10. Technological improvements in the shipbuilding industry

The four resilience improvement strategies in the shipbuilding industry are given in Table 10. In line with the results of previous research conducted by Rajesh (2017), increased product standardization can increase the production flexibility and have a positive effect on resilience. Rajesh (2017) explained that product standardization enhances resilience. Furthermore, having flexible production facilities could enhance resilience. (Kamalahmadi and Parast, 2016; Tang, 2006a; Tomlin, 2006; Tang and Tomlin, 2008; Yang and Yang, 2010; Colicchia *et al.*, 2010).

The resilience attributes used in this proposed improvement are just in time (JIT) delivery and low inventory. This is in line with previous research conducted by Mensah and Merkuryev (2014), which states that JIT delivery and low inventory can minimize waste and inefficiency. Developed technologies and manufacturing method can be summarized as agility (de Moura and Botter, 2017). Information sharing is key for collaboration and risk reduction (Christopher and Peck, 2004), as well as for facing supply chain disruption (Kamalahmadi and Parast, 2016).

Increasing innovation through technology can reduce vulnerability (Tukamuhabwa *et al.*, 2015). Applying rails in shipbuilding costs money but can be used as a long-term upgrade. This is in line with research conducted by Rajesh (2019), which states that long-term technique planning is beneficial. The last cause, lack of training for workers, could be improved by providing appropriate training for the worker to improve their skills. This is in line with research conducted by Rice and Caniato (2003), which states that education and training are the most common practices in resilience.

In Table 10, there are several dimensions of SCR and the accompanying attributes that are used to generate resilience against the causes that occurred in the traditional shipbuilding industry, especially during the COVID-19 pandemic. From the ten causes shown in Table 10, eight of them are related to the use of technology in the traditional shipbuilding industry. Two other causes relate to workers and cooperation between partners in the traditional shipbuilding industry.

4.1.5 Control. The proposed control of activities that interfere with shipbuilding are presented in Table 11. The results of the proposed control come from three experts familiar with conditions in the shipbuilding industry.

Some improvements using an automatic machine to minimize inefficiency are proposed by the authors. Regular maintenance on the machine should be done to ensure optimal performances. This proposed control is in line with research conducted by Singh and Singh (2019). They said that maintenance practice insufficiencies could influence organizational competitiveness by decreasing throughput and production quality and increasing shortages because of work downtime. Au-Yong *et al.* (2016) stated that planned support requires the accessibility of suitable and adequate spare parts to supplant existing parts. The author also recommended safety training to avoid human errors. This is in line with research conducted by Boustras *et al.* (2011), which said that safety training is of fundamental significance.

During the COVID-19 pandemic, the use of ship-launching rails, automatic wood cutting machines, tracker machines, wood drying machines, cranes and wood-bending machines can reduce active worker density, thus satisfying social distancing rules.

4.2 Logistics service industry

4.2.1 Define. From the results of brainstorming with experts, three appropriate CTQ outputs were obtained, which were unsuitable quantity, standard leadtime and ontime delivery. After the CTQ had been identified, it is necessary to use the STS delivery map process to determine the non-value-added activities in Figure 3. The STS delivery logistics service business process is different from the types of couriers and delivery services in general. In STS delivery, the logistics company must take the goods directly from a store according to the request sent. In contrast to door-to-door delivery, where the final destination is the consumer, deliveries are made in large quantities between cities and islands.

The store send goods to the logistics service company with documents in the form of data, and an email confirmation. A delivery schedule is provided with an estimated time according to each destination city. After scheduling, the goods will be picked up by the transportation chosen (pick up truck) to the sender's store to be sent to the recipient's store. Before they are sent to the destination store, the goods are checked. After the goods arrive at the recipient's store, the company will entry the data into its system.

4.2.2 Measure. This is the second stage in LSS with the DMAIC model. During this measure stage, a defect assessment was carried out in the STS process. From the

Cause	Recommended improvements	Proposed control
There are no ship launch rails	Applying the use of rails at ship launching to avoid hull damage	– Ensure that the rail line to be used for ship launching is in good condition and ready so that the ship launching can avoid obstacles *(best practices)* – Provide directions to operators or field officers to ensure that the ship to be launched is in the right position and appropriate so that the ship can be launched properly *(best practices)*
Raining	Facilitating a shipbuilding place by installing a roof (indoor) so the production process will not be disturbed when it rains	– Perform regular maintenance on the roof at least every six months *(in house)* – Ensure that the roof (indoor) used is in good condition or does not leak so that when it rains, there are no obstacles *(in house)*
There is no automatic cutting machine	Using automatic wood-cutting machines for more standardized wood cut results because it can increase production flexibility and enchance resilience	– Making SOPs and apply safety training to prevent an accident when using automatic cutting machine *(best practices)* – Perform regular maintenance on the machine *(best practices)* – Provide spare parts that can be used to repair machines when there is a breakdown while the shipbuilding work is in progress *(best practices)*
There is no trecker machine (removing boring)	Providing tracker machines/tools to increased efficiency and productivity, reduced errors, rework and risk rates, improved worker safety, improved customer satisfaction	– Perform regular maintenance on the machine *(best practices)* – Provide spare parts that can be used to repair machines when there is a a breakdown while the shipbuilding work is in progress *(best practices)*
Lack of training for workers	Providing appropriate training for the worker to improve their skills	– Evaluate the training that has been carried out *(government regulation)* – Make a good plan for the training that will be carried out next *(best practices)*
There is no wood dryer	Using an oven or a wood-drying machine to minimize waste and inefficiency. Continuous improvement in quality, productivity and responsiveness	– Making SOPs and apply safety training to prevent an accident when using automatic cutting machines *(best practices)* – Ensure that the amount of wood to be dried in the wood dryer (oven) is in accordance with the machine capacity *(best practices)* – Perform regular maintenance on the machine *(best practices)* – Provide spare parts that can be used to repair machines when there is a a breakdown while the shipbuilding work is in progress *(best practices)*

(*continued*)

Table 11. Proposed control of shipbuilding

Cause	Recommended improvements	Proposed control
There is no crane machine	Using a crane machine to make it easier to lift wood from the bottom to the top of the shipbuilding so that can reduce vulnerability and prevent work accident	– Making SOPs and apply safety training to prevent an accident when using a crane machine *(best practices)* – Ensure that the amount of wood to be transported by the crane machine is in accordance with the carrying capacity/load of the crane machine *(best practices)* – Perform regular maintenance on the machine *(best practices)* – Provide spare parts that can be used to repair machines when there is a a breakdown while the shipbuilding work is in progress *(best practices)*
There is no wood-bending machine	Using a wood-bending machine to avoid damage to the wood so that the result can valuing the product and service	– Making SOPs and apply safety training to prevent an accident when using a wood-bending machine *(best practices)* – Perform regular maintenance on the machine *(best practices)* – Provide spare parts that can be used to repair machines when there is a a breakdown while the ship building work is in progress *(best practices)*
Cutting wood by rental is still semi-manual	Collaborating with partners, for example, cutting services for wood to schedule and post-information in real time using the application	Supervise and collect data on wood-cutting activities so that wood-cutting activities can run normally, do not lack capacity or queue brcause of excessive loads *(best practices)*
The ability of each worker is different	Providing guidelines or SOPs that are easily understood by each worker so that the results of the work are in accordance with the standards (do not vary) from one worker to another	– Supervise/monitor the work performed by each worker *(best practices)* – Give the directions if the workers do work that is not in accordance with the SOP *(best practices)*

Table 11.

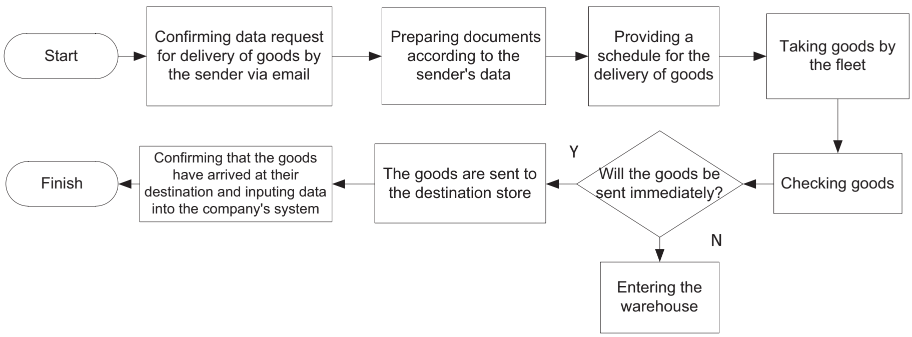

Figure 3.
Process map of STS

brainstorming process with the experts, CTQ is identified, and next the DPMO is measured. The following formula is used to determine the value.

$$\mathrm{DPMO} = \left(\mathrm{D}/(\mathrm{U\,x\,O})\right) \mathrm{x}\, 1,000,000$$

where DPMO indicates defects per million opportunities; Dis the number of defects; U is the number of units; and O is the number of opportunities that will result in defect.

In Table 12, the data collected before COVID-19 pandemic are from January to March. The pandemics recorded in Indonesia began from April to August. Results of the DPMO and sigma calculation are recorded in Table 12.

From Table 12, it can be concluded that the average of DPMO value is still quite high (73,755.73) during January to August. This means that in one million opportunities there will be as many as 73,755.73 possibilities that the delivery process will produce defects. If the company keeps maintaining these failures without doing any continous improvement to the whole process, it will significantly affect its performance and customer satisfaction.

4.2.3 Analyze

4.2.3.1 Waste analysis. Based on the interview results, it can be identified that the activities that result in waste on delivery were divided into several sub-criteria waste. Further details of each sub-waste can be seen in Table 13.

The type of waste used is different from waste manufacturing in general. In this research, it is called a "service waste" according to the concept proposed by Andrés-lópez *et al.* (2015), which covers the eight types of service waste. Although eight service waste types were listed, only six service waste were identified under this STS delivery type logistics service company. Furthermore, from the 6 types of service waste, there are 16 sub-criteria wastes obtained from the results of brainstorming with the experts from the internal company.

4.2.3.2 Fishbone analysis. To find out the causes of the waste, it can be broken down into the fishbone diagram as shown in Figure 4. Of the three CTQs, only one was chosen to serve as the fishbone head, which was the "Unsuitable quantity." Additionally, the main branches stand as the type of cause which were divided into six variations. The smaller branches were meant to describe the detailed causes of each variation.

"Unsuitable quantity" was chosen as the fishbone's head because of its huge after-effects. Several problems caused it, including people, internal processes, order management, delivery, warehouse management and a pandemic situation. A detailed explanation regarding the root of the problem and its sub-sections, which cause a mismatch between the quantity of goods ordered and at the time of collection, is as follows:

Year	Month	Total quantity	Defects	CTQ	DPMO	Sigma
2020	January	115.77	15.77	3	45,406.12	3.19
	February	101.70	1.70	3	5,571.94	4.04
	March	106.19	6.19	3	19,430.58	3.57
	April	100.00	0.00	3	0.00	0.00
	May	100.27	0.27	3	897.58	4.62
	June	99.29	−0.71	3	−2,383.59	4.32
	July	145.14	45.14	3	103,670.02	2.76
	August	258.95	158.95	3	204,608.35	2.33
Total		1,027.31	227.31	3	73,755.73	2.95

Table 12. Logistics service DPMO and sigma calculation

Table 13.
Service waste category

No.	Type of service waste	Sub-criteria waste
1	Overproduction	–
2	Delay	Undisciplined and careless driver Incomplete documents Unsuitable quantity
3	Un-needed transport or movement	Second goods retrieval Vehicle re-parking
4	Duplication	Manual record Several people in one file
5	Lack of standardization	Unstandardized SOP
6	Failure demand Lack of customer's focus Obsolescence/inadequacy Loss of opportunity Miscommunication	No order limitation No quantity updated info Less number of transportations Physical distancing Miscommunication
7	Underused resources	–
8	Manager's resistance to change	Stubborn manager Unreliable manager Unaware manager

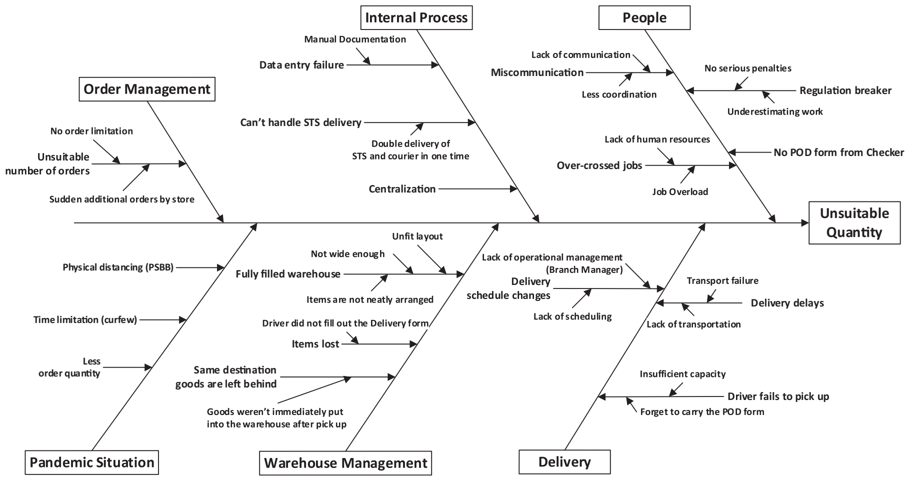

Figure 4.
Fishbone analysis of logistics service

- People

  People can be the cause of the problem in lean manufacturing. Some of the sub-causes were miscommunication, irregulaties, undelivery form and over-crossed jobs. Miscommunication in this case is because of the lack of coordination.

- Internal process

  The internal process failures are because of data entry errors.

- Order management

  The number of order requests is more than the quantity ordered.

- Delivery

Delivery is one of the crucial things that must be considered. In case of the logistics company who delivers goods to the customer, good scheduling is a mandatory. If the goods did not deliver in time, the customer satisfaction and trust would be highly affected.

- Warehouse management

  Warehouse layout is needed in running a logistics service business. In the shipping companies under study, the warehouse has an unfit layout.

- Pandemic situation

  This pandemic situation includes the existence of physical distancing and lockdown in some cities around Indonesia. Curfews and reduced orders result in fewer profits.

After assessing the FMEA analysis, the RPN number could be found. Detailed results of each RPN number were obtained according to Table 14. RPN 1 and RPN 2 represent the RPN result conducted by each expert from the internal company. Hence, AVR represents the average value of RPN 1 and RPN 2.

From the FMEA analysis, it is known that the RPN value used as the research boundary is the best-five causes with the highest RPN value. This limitation is based on the agreement between the researcher and the internal experts of the company. The five causes in order were items lost, delays in delivery, goods in the same destination are left behind delivery, fully filled warehouse and miscommunication.

4.2.4 Improve. The proposed improvements can be implemented by the research object company for continuous improvements. Table 15 is a list of resilience measures after consulting with the internal company experts. The resilience measures were chosen from the resilience capability in agility.

In the STS activity, there were five suggestions for improvement according to the problems that often occur in the company. The first is the problem of lost items, proposed by experts for the provision of a practical delivery form. The delivery form serves as a goods delivery proof or receipt number; with a practical form, it is hoped that the location of goods can be traceable for consumers. Some items have not yet been given a delivery form;

Cause	RPN 1	RPN 2	AVR	Rank
Items lost	168	144	156	1
Delivery delays	168	96	132	2
Same destination goods are left behind	49	192	120,5	3
Fully filled warehouse	42	168	105	4
Miscommunication	98	98	98	5
No delivery form from checker	81	90	85,5	6
Data entry failure	6	150	78	7
Unsuitable number of orders	12	140	76	8
Can't handle STS delivery	84	64	74	9
Drivers fail to pick up	48	72	60	10
Over-crossed jobs	18	100	59	11
Break the regulation	24	72	48	12
Changed delivery schedule	48	48	48	12
Physical distancing (PSBB)	40	32	36	13
Centralization policy	12	16	14	14
Reduced order numbers	8	16	12	15
Time limitation (curfew)	8	4	6	16

Table 14. RPN (risk priority number)

therefore, the form should be made as practical as possible, so that employees can easily list the goods into the delivery form. This practical form identicates that the company has implemented one of SCR's dimensions, which is flexibility. As stated by Ishfaq (2012), flexible strategy in multi-mode transport companies will reduce high operational costs, because the alternative routes will be used during disruptions. Meanwhile in this study, the high cost emerges mostly because of items being lost in both inbound and outbound processes. The internal experts said that these losses were usually caused by the checker, who regularly forgets either to prepare or fulfil the delivery form.

Second is the delay in goods delivery, which often occurs in other logistics services, which is dealt with using different strategies by each company. In this company, the problem is that the delivery of goods is delayed because of transport problems and inaccurate time estimates. Technological capability improves company resilience and competitiveness (Jain *et al.*, 2017). Therefore, it is proposed to provide an alarm reminder for the delivery schedule; this step can be applied to an email calendar or a separate application and system. It is hoped that with this alarm, it will be easier for the employee to remember that the delivery scheduled for the goods has to be processed. Because delivery scheduling is a key resiliency component (Kayikci, 2020), this will greatly impact the company's performance.

The three goods, whose destination is behind the same delivery, are given a recommendation to improve in the form of an automatic data collection of incoming goods; this step is proposed for optimal systemization. This can make it easier for employees to check which items are sent with the same schedule and destination, to maximize the pick-up load and avoid lagging goods. With this automatization, employee will easily check any goods. So far, the problem with this company is that the data entrying and checking are done manually, so that this can cause a frequent lagging of goods and poor transport management. The development of new automation systems to assist the operational performance of the service-based company is strongly recommended, which will significantly reduce human error. In addition, this strategy will improve the service quality and is key to gaining high customer satisfaction (Bühler *et al.*, 2016).

The fourth is a fully filled warehouse: in the object research company, the goods will enter the werehouse, and then are sent to the store (recipient). This company has experienced problems with overloaded goods in warehouse. Therefore, a suggestion was given to improve the layout. This is supported by the condition of the company that still has not implemented an appropriate layout when the goods arrive, the goods are immediately placed on an empty chart and there is no appropriate space division or grouping according to the type, purpose or name of the goods. With the layout improvement, it is hoped that the goods can be neatly arranged and can make employees easier to find the goods that will be sent. This suggestion agrees with the findings that a well-managed warehouse improves supply chain visibility and resilience (Jain *et al.*, 2017).

Basically, every company has its own steps to minimize this miscommunication. Liu and Lee (2018) showed that internal company integration improves employee cooperation

Table 15.
Resilience measures for improvement

Cause	Dimension	Resilience attribute
Items lost	Agility	Practical delivery form
Delivery delays		Scheduled delivery reminder
Same destination goods are left behind		Automatic goods entry record
Fully filled warehouse		Warehouse layout improvements
Miscommunication		Internal company integration

through integration, namely, by enhancing information flow, service efficiency and cash flow. Supply chain resiliency could also be enhanced through various employee creativity inputs (Pettit *et al.*, 2013).

4.2.5 Control. Table 16 lists out five enduring solutions that can be applied in the internal systems of the research object company. The number of solutions chosen is adjusted to the best five number of problem's causes. As for the specific control action, several resilience measures have been proposed using one of the SCR's dimensions, which is robustness. These results were referred to the company's internal expert.

After being given a recommendation for improvement, so that this can be carried out properly, proper control is needed. First, the problem of items lost can be monitored and maintained; this can be applied with more attention to things to protect the goods until the goods are received at the recipient's store. Thus, the logistics service company should keep monitoring and maintaining all their goods regularly. In research conducted by Lam and Bai (2016), this solution was mentioned as the second most effective resilient measure. Meanwhile, in Kayikci's (2020), "maintenance" was stated as the highly impacted resilience measure that impacted global freight transport companies the most.

Second, delivery delays can be controlled by scheduling accuracy: this can be achieved by ensuring that the estimated delivery of goods is well-received by the recipient store, and by ensuring clear timing and communication between employees. If there is often a mismatch in estimating incoming goods, the company can conduct an evaluation to make a more appropriate estimate of the schedule (time of arrival). Scheduling customer orders beforehand prevents disruption risks (Sawik, 2013), increasing SCR.

Third, goods with the same destination are left behind in delivery: this can be further maximized with the good transport management. The company must ensure that the transports are well-managed. With the proposed system of incoming goods at the beginning, it can make it easier for transports to find out which goods will be sent according to the same estimated destination and delivery time. This can maximize the transport load. Another factor that is also considered is the appropriate number of drivers and transport maintenance, so that unwanted things will never harm the company. Vehicle maintenance also improves the end-to-end order delivery performance, thus enhancing supply chain visibility (Jain *et al.*, 2017).

Next is warehouse management control: it is hoped that the company can pay attention to warehouse management, so that the flow of the goods placement can be placed according to the better layout. This can make it easier to find any items. With the control of warehouse management, all activities in the warehouse will be more disciplined, and it is hoped that there will be no problem of an overstock. Warehouse management, of course, refers to the beginning of the goods entering the warehouse, maintaining the goods in the warehouse until the goods leave the warehouse and being sent to the recipient's store. This proposed solution is in line with that of Jain *et al.* (2017), which states that coordinating the flow of goods, services, information and cash within and across boundaries expands SCR.

Cause	Dimension	Resilience attribute
Items lost	Robustness	Supervision and maintenance
Delivery delays		Strong *scheduling*
Same destination goods are left behind		Transport management
Fully filled warehouse		Warehouse management
Miscommunication		Collaborative communication and Information sharing

Table 16. Control phase resilience measures

Furthermore, miscommunication can be controlled by collaborative communication and information sharing. The company can conduct periodical evaluations of employee performance and cooperation. Forums and consultations can be held, so that the communication between employees can run well. This can also be improved during the COVID-19 pandemic, where the Work From Home (WFH) system was carried out regularly against companies. This could make miscommunication between companies more likely. For this reason, collaborative communication is of greater importance. As stated by Saenz and Revilla (2014), collaboration with manufacturers, suppliers, logistics and transport providers on risk management activities and sharing information about risk critical nodes is needed. The more transparent the information is, the more collaborative the supply chain relationships will be (Jain *et al.*, 2017).

4.3 Shipping industry

4.3.1 Define. At this stage, identification is carried out to determine the CTQ. From the data obtained by conducting interviews with shipping company owner, there are four characteristics included in the CTQ, namely, freight, vessel performance, communication and payment system. After the CTQ was identified, it was found that the customer's expectations were not fulfilled because of defects. The definition of "defect" in the company is when there is a delay in the maximum operating days, which is determined by the company's key performance indicators (KPIs). The initial stage in process improvement is carried out by describing the flow of the unloading process using the process map as shown in Figure 5.

The targets of this shipping industry research are the private shipping companies in Surabaya, Indonesia. The main cargo in this company is coal, which needs to be carried to the state-owned power generation coal stockpile. Coal is the main cargo of the company because other cargoes such as fertilizer and cement pose a risk of damage to cargo and the vessel. This company was selected for research because of COVID-19's impact of reduced coal cargo loads on shipping companies. Reduced demand for coal because of reduced electricity integrity, as well as the shutdown of offices, schools, university, etc., contributes to this phenomenon.

Figure 5 views the business process, starting in the vessel's departure to the coal port of loading in Adan Bay, Indonesia. Coal is loaded into the ship, and the vessel departs to the port of unloading (at a coal stockpile of a state-owned power generation) at Cilacap, Indonesia. After unloading the coal, the vessel returns to the port of loading.

4.3.2 Measure. The measure stage is the second step in implementing LSS with the DMAIC model. At this stage, the measurement of the defect level that occurred in shipping companies was carried out during 2019 (before being affected by COVID-19) and in 2020 (after being affected by COVID-19). The total amount of data used in this research comprises

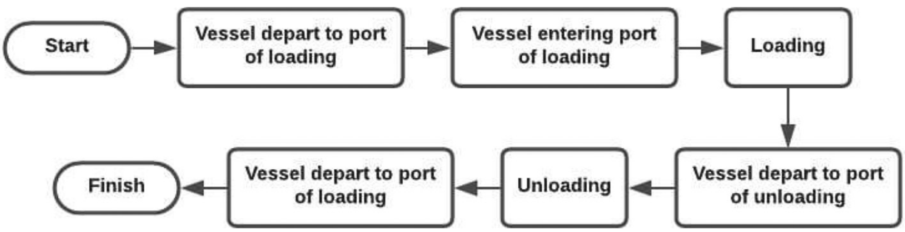

Figure 5.
Business process of shipping companies

54 data points documenting the departure and arrival of two company-owned vessels from 2019 to July 2020 in the Adan Bay-Cilacap circuit. To indicate the defects created by each vessel, the company has the standards listed in the company's KPI. The maximum operational time for an Adan bay-Cilacap trip is a KPI of 18 days; each voyage that exceeds 18 days is considered a defect. Quality level (sigma) can be converted from DPMO to sigma value based on Motorola's Six Sigma process (normal distribution shifted 1.5-sigma) (Gaspersz, 2015). The results of the calculation of the DPMO value and the sigma level can be seen in Table 17.

From Table 17, it can be concluded that the average DPMO value before being affected by COVID-19 was smaller than after being affected by COVID-19. This value can be interpreted as, prior to COVID-19, a likelihood of 108,695.652 defects in one million opportunities. After COVID-19's effects, in one million opportunities, the likelihood increases to 109,375. The value of DPMO after affecting by COVID-19 is greater because some potential risks form the defects. The potential risks emerge as an impact of COVID-19. The potential risk will be explained further in the analysis section.

4.3.3 Analyze

4.3.3.1 Waste analysis. Based on the results of interviews that were conducted, activities that cause inefficiency in the shipping companies can be identified. Here, waste is defined as service waste such as overproduction, delay, unneeded transport or movement, duplication, lack of standardization, failure demand/lack of customer's focus/obsolescence/inadequacy/loss of opportunity/miscommunication, underused resources and manager's resistance to change (Andrés-lópez *et al.*, 2015). In the research object company, only a few wastes were deemed as significant, and are listed in Table 18.

From the table above, there are five wastes in the company, namely, delay, un-needed transport or movement, lack of standardization, lack of miscommunication and underused resources. One consideration that is not included is overproduction because a shipping service

Year	Month	Total departures	Defect	CTQ	DPMO	Sigma
2019	January	3	0	4	0	0
	February	3	2	4	166,666.667	2.467
	March	1	1	4	250,000	2.174
	April	3	1	4	83,333.333	2.883
	May	3	2	4	166,666.667	2.467
	June	2	1	4	125,000	2.650
	July	4	2	4	125,000	2.650
	August	1	1	4	250,000	2.174
	September	0	0	4	0	0
	October	0	0	4	0	0
	November	2	0	4	0	0
	December	1	0	4	0	0
Average		23	10	4	108,695.652	2.733
2020	January	3	2	4	166,666.667	2.467
	February	2	0	4	0	0
	March	2	0	4	0	0
	April	3	1	4	83,333.333	2.883
	May	3	1	4	83,333.333	2.883
	June	2	2	4	250,000	2.174
	July	1	1	4	250,000	2.174
Average		16	7	4	109,375	2.723

Table 17. Sigma calculations of a shipping company

does not produce products. Duplication waste is also unlisted as the bulk carrier shipping companies only handle one customer per voyage. To determine the causes of the waste, a fishbone analysis is performed:

4.3.3.2 Fishbone analysis. The following fishbone diagram is the result of interviews from the shipping companies:

Based on Figure 6, it can be explained that the results of the fishbone diagram analysis are as follows:

- Man

  In the human factor, there are two problems that impact inefficiency in shipping company operations. The first problem is the lack of standardization in the working procedure and in the departments. The second problem is underutilization of existing resources.

- Machine

  In this factor, two problems impact inefficiency in shipping company operations. The first problem is machine failure, which is caused by inadequate maintenance and over-operational capacity. The second problem is crane failure, which is also caused by inadequate maintenance.

- Material

  In material factors, there are two problems that impact inefficiency in shipping company operations. The first problem is delays caused by internal preparations, whereas another cause is high coal stockpiles that create queues at the loading port.

Table 18.
Shipping company service waste

No.	Type of waste	Waste
1	Delay	Delay in loading and unloading cargo
2	Un-needed transport or movement	Deviation route because of the unexpected problem (e.g. fuel-filling problem)
3	Lack of standardization	Lack of standardization in managing the human resource
4	Lack of customer's focus/ miscommunication	Waste in method to operating the vessel
5	Underused resources	Unproductive of human resource

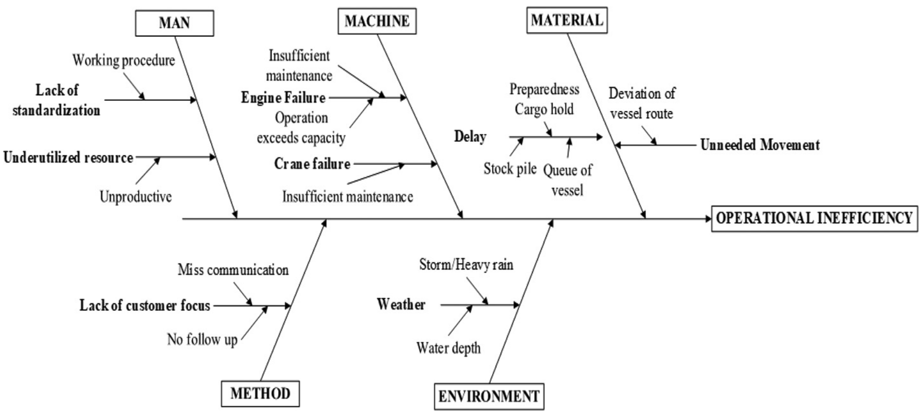

Figure 6.
Fishbone diagram of shipping company

The other problem is the un-needed movement that deviates the vessel route because of unplanned refueling requirements.

- Method

  In the method factor, there is one problem: lack of customer focus, which is caused by a lack of follow-ups by each party and vessel operation miscommunications.

- Environment

  Regarding environmental factors, there are two problems that impact inefficiency in shipping company operations. The first problem is because of inadequate port facilities, such as water depth, that interfere with operational activities while the ship is berthed. Then, the second problem is inclement weather because of heavy rain that interferes with the operational, loading and unloading of the vessel.

The next analysis continued using the FMEA method, so that the RPN value of the top five will be obtained from the 13 root causes in Table 19.

Based on the number of RPN values, the root causes included in the top five rankings are high inventory in the coal stockpile, queue of vessels at the port of unloading, lack of preparedness in handling loaded cargo, engine over-operating capacity and less productive workers. The full stockpile at the unloading port is the biggest root of the problem, which affects the operational inefficiency in shipping companies. A possible main cause is that the pile of excess coal loads can create queues of ships at the dock, causing delays in the loading and unloading process. Queuing of ships at the loading port is the second biggest root cause with the same value, because time queuing for ships that remain for too long could delay the loading and unloading process, so that ship operations become inefficient. Lack of readiness for cargo to be loaded is the root of the third problem affecting operational inefficiency, because of delayed loading and miscommunication. Engine failure because of excess operating capacity is the fourth root problem that affects operational inefficiency, because if the ship's engine operates continuously but lacks inspection and maintenance, the ship can cease to

Potential failure types		Cause	Sev	Occ	Det	RPN	Rank
Human							
Lack of standardization	1	Less standardized work procedures	5	2	2	20	7
Less use of SD	2	Less productive	5	3	2	30	5
Material							
Delay	3	Readiness of loaded cargo	7	2	3	42	3
	4	The stockpile was filled	8	7	7	392	1
	5	Queue of ships at the loading port	8	7	7	392	2
Movements that are not needed	6	Ship line deviation	3	2	3	18	11
Method							
Lack of consumer focus	7	Arrival meeting	5	2	2	20	8
	8	There is no follow-up	5	2	2	20	9
Machine							
Engine failure	9	Inadequate machine maintenance	7	2	2	28	5
	10	Engine over-operating capacity	8	2	2	32	4
Crane failure	11	Inadequate crane maintenance	7	2	2	28	6
Environment							
Weather	12	Lightning/heavy rain	5	2	2	20	10
Port facilities	13	Water depth	8	2	1	16	12

Table 19.
Risk priority number

operate. Finally, workers who are less productive are the root of the fifth problem, which affects operational inefficiency, because work times become ineffective and suboptimal.

4.3.4 Improvement. At this stage, recommendations of improvement refer to the perspective of SCR management in shipping companies. The resilience dimensions that researchers want to develop in the improvement stage of the shipping companies are collaboration, flexibility and agility. Collaboration is considered an important factor in SCR because it relates to sharing information between various parties (Carvalho *et al.*, 2012), which is necessary for rapid responses in a pandemic situation. Flexibility became one of the important aspects that should be developed by the company, especially in a pandemic situation. Flexibility shows how companies can adapt effectively during disturbances. So, flexibility must be considered in shipping companies. Finally, agility focuses on "rapid system reconfiguration in the face of unforeseeable changes" (Bernardes and Hanna, 2009). One of the big problems that occurs during a pandemic situation is the instability of demand for goods. So, agility criteria must be defined for shipping companies. The resilience measure is designed in the SC at the strategic level. Resilience measures used in shipping companies are contingency plan; forecast accuracy; strategic alliance and supply chain relationship management; advanced IT system; and monitoring and maintenance (Lam and Bai, 2016). These proposed improvement recommendations were obtained from interviews with the owner of the shipping companies. All proposed improvement recommendations were based on company procedure, except for the proposed improvement for risk of vessel queuing at the port of unloading, which was obtained from government procedure. They are shown in Table 20.

From Table 20, it can be seen that there are five root causes of potential inefficiency risks for ship operations. Three of the five problems were caused by the impact of the COVID-19 pandemic; these potential risks are high inventory in coal stockpiles, vessels queues at the

No.	Description of potential risk	Resilience measure	Proposed improvement
1	High inventory in coal stockpile	Forecast accuracy Strategic alliance	Reduce coal supply
2	Queue of vessel at the port of unloading	Forecast accuracy	Coordination with the coal recipient (state electricity enterprise)
3	Lack of preparedness in handling loaded cargo	Supply chain relationship management Supply chain relationship management Contingency plan Advanced IT system	Coordination with mining parties
4	Engine over-operating capacity	Monitoring and maintenance Contingency plan	Periodical maintenance needs to be done to lower the risk of technical breakdown Providing capacity in excess of requirements and prior to the point of need, as well as establishing a contingency plan
5	Less productive workers	Monitoring and maintenance	Reporting of inactive loading and unloading staff at the recipient
		Contingency plan	Giving routine meetings and briefings before works

Table 20.
Proposed improvements

port of unloading and lack of preparedness in handling loaded cargo. The risk of high inventory in coal stockpile is because during the COVID-19 pandemic, there were many public shutdowns such as schools, offices, malls and others, causing low electricity consumption, which resulted in a decrease in coal demand that resulted in high inventory of coal in the stockpile. The owner proposed to use forecast accuracy and strategic alliance in resilience measures by reducing coal supply, especially in a pandemic situation. This proposed improvement is in line with the previous research of Bottani and Rizzi (2006), who said that high inventory risks can be reduced by increasing forecast accuracy to lower inventories and increase SC visibility and responsiveness. Huang *et al.* (2015) also proposed collaborative programs with counterparties to reduce supply uncertainties. These suggestions address the high inventory of stockpiled coal from the many queued unloading ships. Accordingly, the owner proposed to coordinate with the coal recipient (state electricity enterprise). This proposed improvement is supported by the previous research: to overcome the risk of the queue of vessel at the port of unloading, Lam and Dai (2015) proposed cooperation with port operators to enhance information sharing, such as berthing schedules, which increases supply chain transparency. This would then lead to reduced port congestion. The risk of lack of preparedness in handling loaded cargo could be because of the existence of a health protocol in doing work, resulting in less efficiency and a decrease in work speed, so the coordination with the mining parties should be done. This proposed improvement is in line with the previous research of Berle *et al.* (2011). To overcome the risk of lack of preparedness in handling loaded cargo, good supply chain relationships with both customers and suppliers are needed. Lam and Bai (2016) proposed that frequent communication with supply chain partners could reduce the risk of document interpretation problems. Huang *et al.* (2015) also proposed real time tracking systems and databases for cargo. Next, the risk of engine failure is caused by over-operations. The proposed improvements for this problem are periodic maintenance and provision of capacity in excess of the requirements, which matches the studies of Büyüközkan and Cifci (2013) and Berle *et al.* (2011). The risk of less productive workers is caused by the lack of standardization in doing work and unproductive workers. The proposed improvement is supported by the previous research. To overcome the risk of less productive workers, the organizations shall take control and monitor all the activities to ensure that partners and employees perform as expected (Büyüközkan and Cifci, 2013). Lam and Bai (2016) proposed to provide staff training to ensure that the workers are equipped with required skill sets, particularly in dealing with risks and uncertainties.

4.3.5 Control. At this stage, recommendations for improvements and controls that can be applied are made to prevent operational inefficiencies and reduce risks in shipping companies, which are shown in Table 21.

As shown in Table 21, there are proposed controls recommended by researchers based on expert recommendations. To control the coal stockpile inventory problem, the company should hold routine coordination meetings with ship crews, so the information about inventory can always be monitored by each party. Vessel queueing at unloading ports can be controlled by an arrival meeting between ship crew and shipping companies to discuss ship arrival schedules. The time used for unloading processes should be estimated, so that the next ship's arrival schedule is able to avoid congestion at the port. Furthermore, lack of preparedness in handling loaded cargo also can be controlled by a meeting between ship crews and the shipping companies about loaded cargo handling preparations. Engine over-operating capacity can be controlled through routine inspection by shipping authorities. Routine inspection can minimize the error occurrences. Finally, to control less productive workers, companies can do daily monitoring and provide training. The company

No.	Description of potential risk	Resilience measure	Proposed improvement	Proposed controlling
1	High inventory in coal stockpile	Forecast accuracy Strategic alliance	Reduce coal supply	Routine coordination meetings with the ship's crew
2	Queue of vessel at the port of unloading	Forecast accuracy	Coordination with the coal recipient (state electricity enterprise)	Arrival meeting with ship crew, loading and unloading company; coordinating ship arrival schedules
3	Lack of preparedness in handling loaded cargo	Supply chain relationship management Supply chain relationship management Contingency plan Advanced IT system	Coordination with mining parties	Arrival meeting with ship crew, loading and unloading company; communication of ship arrival schedules
4	Engine over-operating capacity	Monitoring and maintenance Contingency plan	Periodical maintenance needs to be done to lower the risk of technical breakdown Providing capacity in excess of requirements and prior to the point of need, as well as establishing a contingency plan	Coordination with shipping authorities; Routine inspection of ships
5	Less productive workers	Monitoring and maintenance Contingency plan	Reporting of inactive loading and unloading staff at the recipient Giving routine meetings and briefings before works	Provide staff training and monitoring

Table 21.
Proposed control

should make standard operational procedures for any class of activities to ensure that all activities are efficiently carried. These proposals are in line with those of Garza-reyes *et al.* (2016a, 2016b), which was a study in ship loading activities. In the case of their project, they established the control measure through the standardization of process and documentation, training, creation of a response plan and application of control charts.

5. Conclusions

We have implemented LSS to measure the performance of a traditional shipbuilding industry in Indonesia. It was found that there were three CTQs, which are cutting error, cracks because of assembly and cracks because of burning for wood bending. The shipbuilding disruptions during the pandemics could be minimized by using the proposed technology in the production process, such as ship-launching rails, automatic wood-cutting machines, tracker machines, wood-drying machines, cranes and wood-bending machines. The usage of those machines could increase the number of ships and maximize the service level while simultaneously supporting the social distancing during the pandemics.

From the results of brainstorming with company experts, we have selected the top five important causes of inefficiency ratings. They were lost items, delivery delays, undelivered goods, warehouse shortage and miscommunication. There are five suggested improvements to overcome the inefficiencies. They are the provision of delivery forms, delivery schedule control, automative data entry, warehouse capacity control and internal company integration. The five controls for the STS process are supervision and maintenance, accurate scheduling, transport management, warehouse management and human resource management.

This research also widens the perspective of SCR management in shipping companies to provide suggestions for improvements to the causes of operational inefficiencies that occur in the shipping business process. It was found that there were four characteristics included in the CTQ; these are freight, vessel performance, communication and payment system. Further research can be carried out with empirical data to support the sustainable shipbuilding business processes in continuous improvement.

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