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## Article

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# Port performance factors and their interactions: A systems thinking approach

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## ABSTRACT

Indonesia's inter-island movement of goods relies heavily on sea transportation because it can transport large volumes of goods at a reasonable cost. However, it is challenging to meet the same pricing standards everywhere, particularly for regions located far from the production centres. The government initiated the Motorways of the Sea Program to tackle this issue. Stakeholders in Indonesia's maritime logistics should be involved in the implementation processes, including the port operators, the shipping industry, and the government as a regulator and infrastructure enabler. However, the democratic, decentralised, and pluralistic nature of Indonesia's government, culture, and bureaucracy has challenged the implementation of the Motorways of the Sea Program. Based on a systematic map of each stakeholder's interests, barriers, and expectations, the study used a systems thinking approach to capture the interactions among stakeholders' activities and policies in the maritime logistics system. A causal loop diagram and a stock and flow diagram were developed to provide a holistic view of the system. Several systemic forces that became the leverages of the system's performance were identified. The most important factors are infrastructure development, both physical and non-physical infrastructures that include information and communication technology, service procedures, and human capital supporting the service system.

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## 1. Introduction

As an archipelago, the Indonesian government sees maritime logistics issues as an important factor in realising equal development throughout the country's broad regions. Maritime logistics have played an important role in Indonesia's economic development, even since the colonial era. The Dutch colonial rulers built elaborate port management systems and maritime logistics to transport commodities across the islands and back to their home country (Poelinggomang, 2016). These developments show how vital maritime logistics are.

At present, the Indonesian government is trying to enhance the state of Indonesia's maritime logistics by implementing a concept called the "Motorways of the Sea Program" (EU, 2001). By

implementing the Motorways of the Sea Program (called *Tol Laut* in the native language), the government is striving to improve Indonesia's maritime logistics performance to decrease its total logistics costs. The Motorways of the Sea Program includes massive infrastructure construction and the modernization of seaports to accelerate the logistics handling processes and enhance the connectivity between islands. In turn, the program is expected to reduce the logistics costs as well as the basic commodity price disparities across the country. It was recorded that the program has yielded 100 highway support vessels and developed 24 (from 86 to 110) maritime highway routes within 5 years since its initiation in 2015 (Office of the Assistant to the Deputy Cabinet Secretary for State Documents & Translation, 2020).

The total logistics costs have always been a focal problem concerning Indonesia's maritime logistics. The geographical characteristics of Indonesia, which comprises almost 20,000 islands, makes Indonesia's trading rely heavily on sea transportation for its ability to move large volumes of goods at relatively lower costs (Siahaan,

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**Table 1**  
Classification of the main stakeholders in the port system of maritime logistics.

Stakeholder Category	Port operators	Port users	Port administrators
<b>Fundamental Roles</b>	Hold the right to operate and provide logistics handling services.	Purchase port services and support the delivery of the service from the port to the end customer (i.e., shipping line, freight forwarders, etc.)	Use regulations or standards to control the operations within the port area.
<b>Other terms with similar roles</b>	Port authority and terminal operators (Notteboom, 2015); port operators (Freeman, 2004); seaports operating managements (Fawcett, 2006).	Ship liners/shipping lines (Berle et al., 2011; Notteboom, 2015); forwarders (Bae, 2017); vessel operators (Bang, Kang, Martin, & Woo, 2012; Berle et al., 2011; Notteboom, 2015), transportation carriers (Brooks, Schellinck, & Pallis, 2011)	Regulators (Duru, Galvao, Mileski, Robles, & Gharehgozli, 2020); cargo ports owner (federal, states, or cities) (Fawcett, 2006); administrative authority (Coppens, 2007); policy makers (Coppens, 2007); the governments (Brooks & Schellinck, 2013)

2013). Nevertheless, Indonesia's logistics performance index was ranked 56th based on the 2018 World Bank Report, which further justifies that Indonesia's maritime logistics have not reached their optimum performance.

A maritime logistics system consists of several stakeholders that interact with each other. Related to the Motorways of the Sea Program and its impact on the complex Indonesian maritime logistics system, it is only natural that the design process and implementation of the Motorways of the Sea Program should also consider many stakeholders in Indonesia's maritime logistics. Although the stakeholders' interests, barriers, and expectations of Indonesia's maritime logistics have been studied (e.g., Sunitiyoso et al., 2019), the interactions among them that result in Indonesia's maritime logistics system have not been well explored yet. On the other hand, to improve Indonesia's logistics performance index, it is important to know the dynamics of stakeholders' activities or factors affecting the system. Therefore, while some other research explores the relationships among stakeholders' activities/indicators statistically, the present study uses systems thinking to identify the interactions among stakeholders in maritime logistics systems through their activities.

Critical system heuristics (CSH) approach was adopted to explore the interactions among stakeholders so that fair port indicators, from diverse perspectives and values among different stakeholders, can firstly be promoted. Furthermore, system dynamics (SD) approach was deployed to map the causal relationships between factors that the stakeholders have agreed upon, so that stakeholders have a better understanding of how they can intervene and improve the maritime logistics systems. At last, this study scrutinises several possible conditions and policies that might affect the port performance.

## 2. Literature review

### 2.1. The complex nature of maritime logistics systems

Defining a maritime logistics system is complex considering the system comprises several elements, activities, and functions related to the supply chain in the context of maritime transport (Panayides & Song, 2013). In recent studies, maritime logistics is broadly viewed to include multi-perspective entities (Ha, 2017; Ha, Yang, & Lam, 2019; Wendler-Bosco & Nicholson, 2020). Entities such as the port authority (terminal operators), port users (ship liner, forwarder) and regulators, are considered to be the main stakeholders (Berle, Asbjørnslett, & Rice, 2011; Ha, Yang, & Heo, 2017; Notteboom, 2015). Although the inclusion of multi-perspectives has helped in comprehending the maritime logistics system holistically, it also constitutes a dynamic system of maritime logistics.

An example of the maritime logistics system component that involves multiple stakeholders is the maritime transport network chain. The network chain is created when cargo movement involves shipping lines, ports, and transportation carriers where each party is

willing to fulfil their unique role to move the cargo (Talley, 2014). However, the roles of each actor in maritime logistics systems are not static, for example, the changes of a port's role. Currently, the port's role is not only handling cargo and storing it, but it has evolved and become an integral part of the global supply chain (Han, 2018).

Another issue related to stakeholders' involvement in maritime logistics is their often-perplexing interactions, especially when the stakeholders are categorised as public and private sectors. Fawcett (2006) studied the dual system of port governance in the United States (US), where governments (federal, states, or cities) own virtually all the nation's major general cargo seaports. But in terms of operations, most of the nation's seaports share a substantial portion of their management with the private sector. At first glance, the ownership regime appears biased toward the government, and yet, in practice, vast portions of many of the nation's largest seaports are leased to private firms to operate and manage. There is a mix of public and private interests in US seaports, and the system seems to function well. Like the US, policymaking in ports, including Flanders in Belgium, is primarily controlled by an administrative authority (Coppens, 2007). Public authorities have a great interest because ports have significant roles in the economic ecosystem of the area governed. However, the degree of involvement and the relevant government level differ among Flemish ports. Port investment projects are financed according to predefined rules, but for specific projects, exceptions are observed. In Flanders, port management is decentralised. Ports are run at the municipal level or by an autonomous body. Fully privatised ports do not exist. The role of the higher authorities in port policymaking is concerned mostly with investments in port infrastructure and how seaport policies are shaped.

In Indonesian context, the government through state-owned companies or directly through ministries/agencies still has the most significant role in port management. However, private sector involvement has started to grow in this area, as one of the government's strategic plans is to enhance the role of the private sector maritime logistics industry (Leung, 2016). The private sector's participation is believed to enhance Indonesia's maritime logistics system by adding their interests to the system operations which are typically conflicting with the public sectors' interests (De Martino, Errichiello, Marasco, & Morvillo, 2013). Nonetheless, it requires collaboration among stakeholders to solve one of the core issues in Indonesia's maritime sector which is connectivity that often leads to imbalanced loads, lower dwelling time, and higher logistics costs (Leung, 2016).

Given these points, the literature has shown multiple entities involved in maritime logistics systems, along with their evolving roles and issues that arise due to their often-conflicting interests. Based on this review, the authors of this research have, however, learned and synthesised the major actors, including their fundamental roles, that should at least be included in scrutinising maritime logistics systems, specifically in Indonesia, as presented in

**Table 1.** Other entities might be included, but it is comprehensible that ports are always the core of maritime logistics systems.

According to Freeman (2004), stakeholder management has proven to be propitiously enabling port operators, as one of the main stakeholders in the maritime logistics system, to manage the interests of all stakeholders to develop the agreed upon and supportive objectives and business strategies for the long-term success of firms. It is in line with a study by Bae (2017), who found that making a strategy should involve external environments such as the market, competitors, and stakeholders. Therefore, it will create the recognition of environmental uncertainty, which can negatively affect the performance of supply chain integration.

The use of stakeholder management principles in port operations and logistic domains are in high demand, and they have been profoundly adopted in the last decade to reconcile the conflicting interests of different port stakeholders. Based on an overview of the interests of different stakeholders, five conflicts of interest were identified. They are (a) environmental protection versus port development (Acciaro, 2015; De Langen P, 2007; Lam, Ng, & Fu, 2013); (b) urban development versus port development (Acciaro, 2015; De Langen P, 2007; de Oliveira, You, & Coelho, 2021; Lai & Cheng, 2003); (c) labour conditions (including wage, job security, union monopolies) versus port development (Brooks & Schellinck, 2013; Brooks et al., 2011; De Langen P, 2007); (d) resident interests (safety, quality of life) versus port development (Acciaro, 2015; De Langen, 2007; De Martino et al., 2013; Lam, Ng & Fu, 2013); and overall economic development versus port development (Coppens et al., 2007; De Langen, Nijdam & van der Horst, 2007; Lam, Ng & Fu, 2013; Schellinck & Brooks, 2014).

Despite the advantages of stakeholder management in solving the conflicting interests among stakeholders, it is still difficult to determine the appropriate port performance indicators given the circumstances between one port and another are rather different. Previous explanations justified that the involvement of stakeholders with their different roles and the bewildering interactions between them in a maritime logistics system add complexity in understanding the system as each stakeholder involved in the system has their own values and criteria in assessing the port performance (Brooks, Schellinck & Pallis, 2011; de Oliveira, You & Coelho, 2021; Duru et al., 2020). By referring to the system of systems methodologies (SOSM) (Jackson, 2019), it can be concluded that maritime logistics systems fall into the category of a coercive context in which the participants (stakeholders) have diverse interests, values, and beliefs.

Under those circumstances, scrutinising stakeholders' activities and interactions is indispensable to comprehend a maritime logistics system, and in turn, to improve the system performance. The complex nature of maritime logistics is most appropriate to be captured using a systems thinking approach.

## 2.2. Port performance indicators and their determinants

Various research in maritime logistics incorporates optimum cross-sectional indicators. Maritime logistics that consists of intricate routes have been analysed using a network analysis and used the port connectivity as a measurement. For instance, a study conducted by Zaman, Vanany and Awaluddin (2015) used a gravity analysis to map Eastern Indonesia and develop efficient shipping networks. Other studies have focused on financial and operational indicators such as firm size, ship size, the ratio of chartered vessels, the use of new vessels, and the formation of alliances to contribute to the financial performance (Bang et al., 2012). On the other hand, some studies argued that port operations are also critical in maritime logistics (Kuo, Lu & Le, 2020; Panayides & Song, 2009).

Despite the various measures in assessing the maritime logistics systems, the indicators used often related to ports as ports are a vital

element in the maritime logistics system (Wendler-Bosco & Nicholson, 2020) and notably contribute to a country's economy (Amin et al., 2021). Ports impact the economy in three possible ways: direct impacts, indirect impacts, and involved impacts (Castro & Coto-Millán, 1997; DeSalvo, 1994; Verbeke & Debisschop, 1996). Fu (2011) analysed the interactions between ports and the economy and found that while ports contribute directly to the economic aggregate, they can also become a bottleneck because of insufficient capacity. Therefore, local ports hinged on efficiency have a growing impact on economic indicators. Furthermore, taking appropriate actions to increase port efficiency can positively affect the GDP (Fu, 2011). The contributions of ports to the economy involve factors such as port revenues, port productivity, the integration with inland transportation, and employment, which are commonly used as port performance indicators. Moreover, factors such as port investment decisions (Lam, Ng & Fu, 2013; Verbeke & Debisschop, 1996; Vrakas, Chan & Thai, 2021) and demand (De Langen, 2007; DeSalvo, 1994) were mentioned to be related to the aforementioned port performance dimensions.

Previous research shows that port performance measures have continuously evolved as the perspectives of stakeholders' interactions have expanded. For instance, De Langen, Nijdam, and van der Horst (2007) proposed new indicators of port performance, in addition to the most widely used throughput volume, which are port-related employment and value-added. Such indicators satisfy the need of the port authority to gain insight into the port performance and are relevant for stakeholders with socio-economic interests. Another study by Brooks and Schellinck (2013) classified common and specific criteria in evaluating port performance from the port users' perspectives. In addition to the aforementioned indicators, the study included other criteria such as real-time information provisions, broad destinations access, responsiveness level, port safety and security, and port reputation. The criteria were further used as port investment decision factors. More recent research also elucidated that the performance evaluation of maritime logistics, including ports, is dependent on the identified stakeholders in the system (de Oliveira, You & Coelho, 2021; Duru et al., 2020; Michail & Melas, 2021).

In general, different studies assess the systems distinctively as the paradigm selection depends upon the research interest and context. Hence, there is no single correct perspective of maritime logistics systems performance measurements. The factors included in the research are, however, commonly associated with the selection of stakeholders under the study. Table 2 summarises the frequently identified factors in maritime logistics systems, including the port performance indicators, by most authors across different literature.

Several studies have suggested significant relationships between port performance indicators and other driving forces using statistical approaches to enrich the comprehension of port management in maritime logistics systems (Bang et al., 2012; Han, 2018; Lai & Cheng, 2003; Xu et al., 2021). However, the interactions among maritime logistics stakeholders are believed to be complex and change over time (Han, 2018). Thus, the relationships between port performance indicators and other factors are supposed to be dynamic as well. Therefore, port performance indicators that are pertinent to the stakeholders involved in the area (Brooks & Schellinck, 2013; Duru et al., 2020) need to be identified, including their relationships with other factors.

Given the ramifications in the maritime logistics system, this study explores the stakeholders' interactions and activities in the maritime logistics system and proposes a systems dynamics approach to scrutinise the structure that determines the appropriate port performance to further infer the maritime logistics performance.

**Table 2**  
Frequently identified factors in maritime logistics.

Literature	Port connectivity (integration with inland transportation, broad destinations access)	Port operations (port efficiency, port productivity, responsiveness level)	Port capacity (throughput volume)	Profitability (port revenues, shipping cost, logistic cost, demand)	Port investment decisions	Port safety and security	Port reputation	Fleet capacity (ship size, ratio of chartered vessels use of new vessels)	Formation of alliances	Economic variables (employment, GDP)
Amin et al. (2021)		✓	✓	✓						✓
Michail and Melas (2021)										
Vrakas et al. (2021)	✓	✓	✓	✓	✓	✓				✓
Duru et al. (2020)		✓	✓	✓	✓	✓	✓			✓
Kuo, Lu and Le (2020)		✓	✓	✓	✓			✓		
Han (2018)	✓	✓	✓	✓						✓
Zaman et al. (2015)	✓	✓	✓	✓	✓					✓
Schellinck and Brooks (2014)	✓	✓	✓	✓	✓	✓	✓			
Brooks and Schellinck (2013)	✓	✓	✓	✓	✓	✓				
Lam et al. (2013)		✓	✓		✓				✓	✓
Bang et al. (2012)								✓		
Brooks et al. (2011)										✓
Fu (2011)		✓		✓		✓				
Panayides and Song (2009)	✓	✓		✓						
De Langen et al. (2007)	✓	✓	✓	✓	✓			✓		
De Langen (2007)										
Coppens et al. (2007)					✓					
Castro and Coto- Millán (1997)										✓
Verbeke and Debusschop (1996)					✓					✓
DeSalvo (1994)	✓									✓

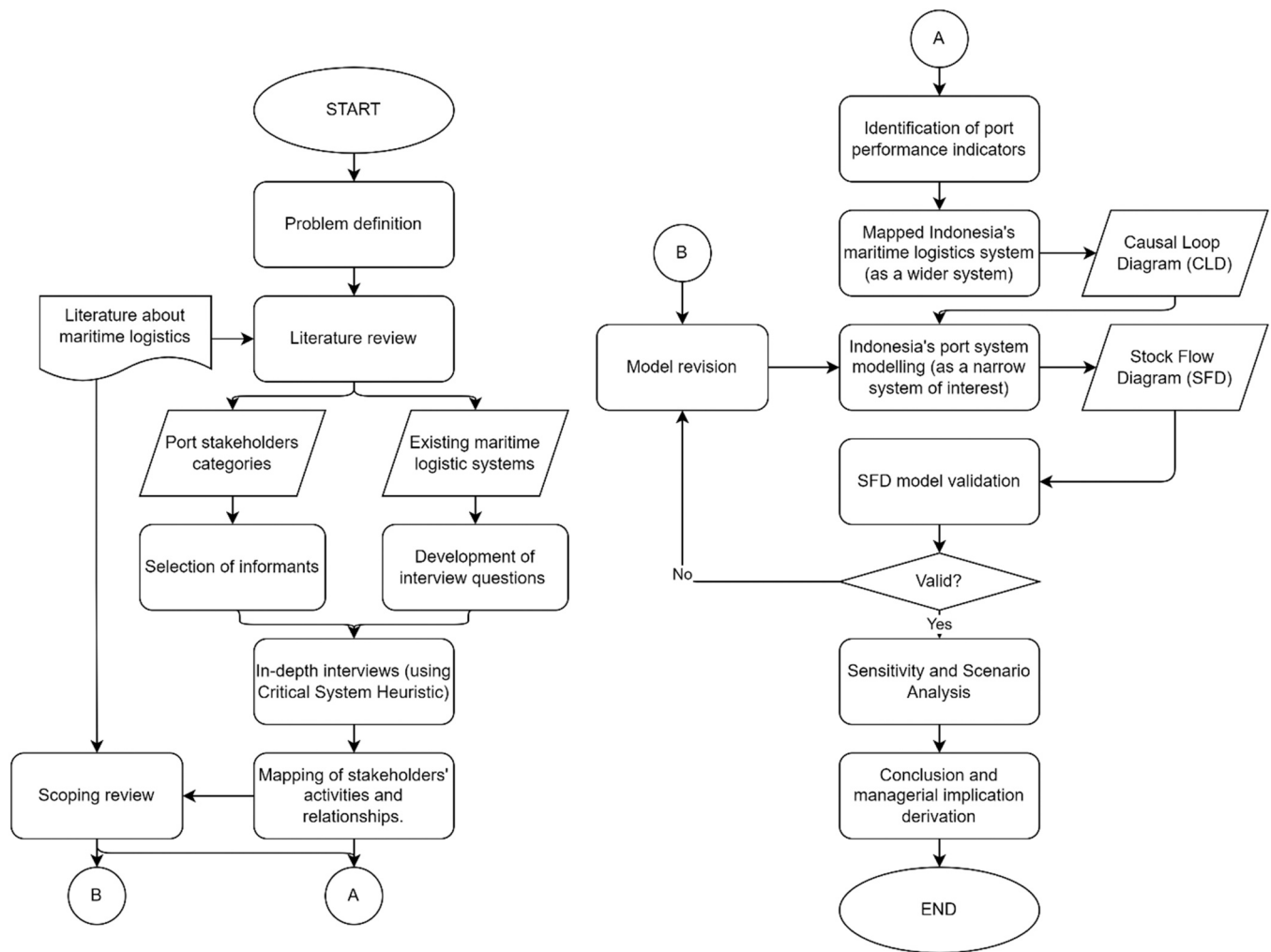


Fig. 1. Research methodology.

### 3. Methodology

To make sense of the complex nature of the maritime logistics systems, this study adopted SOSM (Jackson, 2019, p. 512). The present study used in-depth interviews as the primary data collection method by applying critical system heuristics (CSH) to frame the questions. CSH was used in this study with the initial assumption that the port system could be engineered; however, the participants (stakeholders involved) had different values which fall under the coercive category in the SOSM matrix. As for the data collected, it revolved around the activities and expectations of each stakeholder, especially in implementing the Motorways of the Sea Program in the maritime logistics system, and how they were related to each other.

After conducting the interviews using CSH framework, which allowed the stakeholders to achieve shared values in terms of performance measures (the participants' relationships shifted from coercive to unitary in the SOSM matrix), the analysis evolved to map the complexity of the system by capturing the behaviours of the indicators using a system dynamics approach. The interview results were then analysed and synthesised to develop a causal loop diagram (CLD) and a stock and flow diagram (SFD) that captured the systemic view of the maritime logistics system in Indonesia. Additionally, secondary data from other sources, such as news articles and reports, was acquired. This data was used to support the analysis and justify the mapped system.

Fig. 1 exhibits the methodology used in this study. The details will further be described in the next subsections.

#### 3.1. Selection of informants

Stakeholder identification is one of the critical aspects before conducting the primary data collection process. As aforementioned in the literature review section, oftentimes previous research focuses on the port system as it portrays the vital elements in the maritime logistics systems and factors related to the port system commonly used to infer the maritime logistics systems. Therefore, the present study aims to select the most admissible stakeholders in the scope of port systems to be interviewed as a starting point to comprehend the maritime logistics system. Data related to other stakeholders was acquired from secondary sources.

As stated in several previous studies, the classification of port stakeholders included three categories: terminal operators, port users, and port administrators (e.g., Notteboom et al., 2015; Ha, Yang & Heo, 2017). Another study conducted by Ha, Yang, and Lam (2019) also included experts who had been working in the shipping and port industries for more than 15 years; researchers or academicians in port operations and management; and the government to assess the port performance in container transport logistics based on stakeholders' perspectives. Aligned with the aforementioned studies, Berle, Asbjørnslett, and Rice (2011) also included port operators, shipping companies, and the government as the stakeholders that



**Table 3**

Classification of informants.

No	Category	Name (Initials)	Company/Institution	Business Scope	Title	Working Experiences
1	Port Operator	DRU	P1	Operator but also involved in and comprehend the administrative realm.	Director	More than 12 years as senior management in a port operator
2	Port User	SLP, BMM & PBS	SI	Ranging from shipping (container shipping, tanker, bulk & offshore carrier, shipping management, agency), logistics (ground transportation, container depot, warehouse & distribution centre, third-party logistics service provider, project logistics, cold chain logistics) and port services (cargo loading & unloading, cargodoring, port operations, port support equipment provision)	1 owner; 2 directors	More than 10 years as the Chairman (SLP); more than 10 years as the Secretary of Board of Commissioners & 3 years as the Managing Director (BMM); more than 4 years as the Director of subsidiary company (PBS)
3	Government	RH	KP	Infrastructure provision, policy-making and implementation	Senior commissioner/advisor of the national committee of the acceleration of the priority infrastructure program	4 years as the PMO of the Committee for Acceleration of Priority Infrastructure Delivery

were used as informants in their study of a maritime transportation system. Hence, in the present study, the perspectives were collected from these three categories of stakeholders. Table 3 elucidates the representatives of each stakeholder category.

Despite the limited number of interviewees, the informants covered the three main roles that has been identified in Table 1. Additionally, all the informants have substantial experiences in their respective roles to provide broad perspectives.

The first perspective was obtained from the terminal or port operators (PO) in Indonesia, represented by a state-owned enterprise that provides logistics handling and port operations within the port area. Therefore, the first informant was the director of the largest port operator company in Indonesia, which manages several ports in different islands of the Indonesian archipelago. The respective informant had been working in managing port operators for more than 12 years and was appointed in senior-level positions by several port operators previously. The most valuable experience from the informant was the knowledge and skills regarding international trade and domestic trade since one of the former companies where the informant became a director in a multinational port company operated an international terminal in Indonesia.

The second was the perspective of the port user (PU) in Indonesia, which was represented by an Indonesian private-owned enterprise that has provided shipping and freight forwarder services for decades. This stakeholder can also be seen as a terminal operator since the company also owns and has operated a port in Indonesia for several years. The company built the port infrastructure through a public-private partnership scheme. However, the main business of this enterprise is shipping and freight transport services. The interviewee was the owner of the enterprise itself and two directors of the company. One of the considerations of choosing a shipping and freight transport service to represent the view of the port user was based on the studies of Notteboom et al. (2015) and Schellinck and Brooks (2014), which included shipping agents/lines as one of the port users. In addition, a study by Talley (2014) also included shipping lines as one of the components in their proposed port service chain. In conclusion, the perspectives of the shipping line to represent the port user hopefully can confirm and objectively capture the dynamics of the Indonesian maritime logistics system completely.

The last stakeholder representing the government's perspective was a senior commissioner/advisor in the national committee handling the acceleration of priority infrastructure programs. This study referred to this informant as a government representative (GR). The government trusted this stakeholder to develop and monitor infrastructure planning, feasibility studies, and funding schemes. The commission, where the informant works, focuses on infrastructure development in Indonesia, including toll roads, ports, airports, and renewable energy infrastructure. The experience, especially in toll roads and ports, helps explain the current connectivity situation for inter-island logistics in the Motorways of the Sea Program and maritime logistics.

### 3.2. In-depth interviews of the stakeholders

In-depth interviews were conducted in this study using CSH with the three stakeholders explained in the previous section. There are two modes of analyses in CSH, an 'ought' analysis and an 'is' analysis (Ulrich & Reynolds, 2010), and this study only implemented the 'ought' mode. It helps the authors to structure the situation and assess the intervention from each stakeholder (Ulrich & Reynolds, 2010). As a result, the system of concern, including the stakeholders, their interventions, and the effects of the interventions can be mapped comprehensively.

In summary, the interviews were conducted in a semi-structured manner ranging from 90 to 150 min of duration with four main

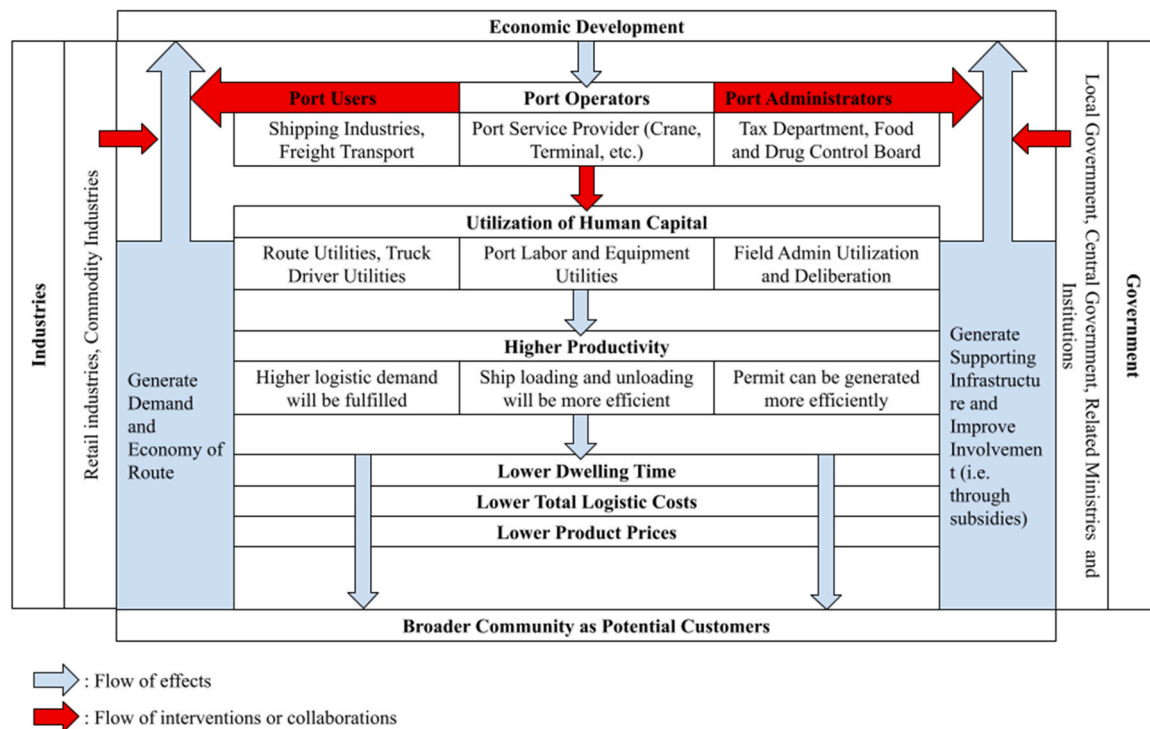


Fig. 2. Stakeholder relationships and the effects and intervention or collaboration among them in relation to their activities.

topics of questions. The first topic was the source of motivation which was aimed to explore the objectives or goals of the system being studied, in this case, the Indonesian Motorways of the Sea Program, which also included the identification of the beneficiaries and the means to measure the system's performance. The next topic was the source of control. This topic was chosen to investigate the stakeholders responsible or involved in making the decisions and the conditions that would support or hinder the implementation of the Motorways of the Sea Program. The third topic asked was the source of knowledge which was aimed to identify the experts and expertise involved to ensure the effectiveness of the Motorways of the Sea Program. Lastly, the source of the legitimacy topic was asked to explore the impact of the Motorways of the Sea Program, including the parties impacted and their opportunities to deliver their aspirations related to the Motorways of the Sea Program.

The interviews were conducted at different times and places, during the period from April 2018 to September 2018. As for the second stakeholder group, which was the port users represented by three persons, the interview was conducted in a group and similar to a focus group discussion.

### 3.3. System dynamics modelling

A causal loop diagram (CLD) was constructed based on essential information provided by the three parties mentioned above to build a big picture of the maritime logistics system in Indonesia. CLD is part of system dynamics, where the variables mentioned in the data collection are connected to other variables in a cause-effect manner (Sterman, 2001). Some variables included in the CLD were derived using the 'ought' analysis of CSH for maritime logistics systems.

It is fundamental to have an understanding about the complex system that the researchers would like to interpret. Therefore, after CLD was constructed, an identification of all the related systemic forces that influence the system's performance was conducted. If the relationships between the variables were considered justifiable by the data collected, then the diagram could be considered accurate.

A stock and flow diagram (SFD) was then used to simulate the model, conduct a sensitivity analysis, and evaluate the scenarios of strategies/interventions. In the end, the results could be utilised as a basis for policy intervention suggestions to accommodate the shared values among Indonesia's maritime logistics stakeholders to further improve the Motorways of the Sea Program implementation regarding Indonesia's maritime logistics system.

## 4. Findings

### 4.1. Stakeholders' activities and relationships

There were three main stakeholders in this research: port operators, port users, and port administrators (or the government) related to the port business and infrastructure. Three other stakeholders were identified after the interviews with the three main stakeholders, who were the community at large (especially the community that will be served by new or improved routes on maritime logistics), the government (especially the local government), and the industry (in some specific terms, the industry is connected to the product distribution and commodity supplier). This study argues that the involvement of the community at large, the local industry, and the local government is important and should be described in its relationship. This claim is based on the interviews with representatives of PO, while the discussion talked about the economic value of shipping routes and port infrastructure development. The routes will have good economic value and impacts if there are contributions and collaboration from the local industry, the local government, and the local community. The relationships among the primary and supporting stakeholders and the activities in the port and maritime logistics system can be seen in Fig. 2.

Based on the results of the interviews, there was a statement from PU that fair collaboration between the government and the private sector, especially local companies, was needed in building the port infrastructure. However, the opportunity for the private sector to contribute to financing the port infrastructure is very limited. This is because the opportunity to finance the development



is prioritised for government-owned companies and foreign-owned private companies. Thus, local private companies can only be involved in financing ports that have low market potential.

In addition, one point was also found from the interview results from the PO that building port infrastructure needs to be supported by the increased market potential of the location where the port is built. This is to provide the volume of trade that occurs at the port so as to improve the quality of investment in port infrastructure development. Therefore, in Fig. 2, generating the demand and economy of routes as well as generating supporting infrastructure and improving involvement are pillars in creating a better scope for port development in Indonesia.

The collaboration amongst the main stakeholders to improve port performance was discussed during the interviews. Human capital is the main issue to provide better productivity based on the interviews with informants from PO and GR. The human capital aspects of the port issues mainly talked about utilities. Despite the technology enhancements as a primary strategy that has already been applied, the informants from PO said that the improvements in the system and technology would be worthless if the human capital is not improved first-hand. This is due to the technology that will not be fully utilised if the human capacity is not well prepared. Thus, improving the human capital skills and knowledge in each entity is imperative since it can enhance the overall port productivity. Moreover, by integrating the human capital knowledge, better port performance can be created (Eon-Seong & Dong-Wook, 2010), for instance, through customised service generation (Vural, Göçer & Halldórsson, 2019).

Nevertheless, the development of technology would have a remarkable impact to provide better performance for humans. In the interview with PO, the technology delivered an integrated system where port labourers and administrators can work easier and transparently, such as through a cashless system to avoid corruption (Garg & Panchal, 2017; Mieseigha & Ogbodo, 2013) and with an increased quality in support service and customer satisfaction (Mawaddah, Prasetyo & Darnoto, 2019), since they provide faster, simpler, and clearer transactions. In the end, rather than choosing human capital as the first priority compared to technology development, it should be hand-in-hand between them because technology can increase the utility of humans themselves.

It also should be remembered that port activities and businesses mainly focus on service (Vural, Göçer & Halldórsson, 2019) where human capital is the main part. Correspondingly, the enhancement of human capital will result in higher productivity and decreasing service time which delivers lower logistics costs. Consequently, customers will get products at lower prices.

#### 4.2. Port Performance Indicators

Concurrent with the stakeholders' activities and relationship mapping, an 'ought' analysis of CSH for the maritime logistics systems matrix was developed to capture the involved and affected actors, as well as the sources of interests within the system comprehensively (Table 4).

In Table 4, the "Specific Concerns (Stakes)" column comprises factors that can be acknowledged as key performance indicators for a port in Indonesia. The identified factors were found to be aligned with several factors listed in Table 2. Such factors were justified according to the previous literature using the scoping review as well.

The following list discusses the identified factors.

- Productivity** deals with technology, machines, and labour utilisation within the port operational systems. In the previous research, productivity is one of the port performance indicators (Brooks, 2006; Cullinane, Song & Gray, 2002; De Monie, 1987; UNCTAD, 1976; Woo, Pettit & Beresford, 2011). From the

**Table 4**  
Ought analysis for the maritime logistics system.

Source of Influence	Boundary Judgments Informing Maritime Logistics (S)			The involved
	Social roles (Stakeholders)	Specific concerns (Stakes)	Key Problems (Stakeholder issues)	
<b>Source of Motivation</b>	1. Beneficiary Port users.	2. Purpose Minimise the total logistics costs that should be paid by port users.	3. Measure of Improvement Reasonable prices and stable demand at the destination to transport the product to the public.	<b>The Affected</b>
<b>Source of Control</b>	4. Decision Maker Government and port operators.	5. Resources The dwelling time in the port and the balance of demand and supply.	6. Decision Environment The definition of dwelling time must be clear and standardised to measure performance in a transparent and fair manner. The market environment must provide a balance of supply and demand to obtain efficient maritime logistics.	
<b>Source of Knowledge</b>	7. Expert Government and port users.	8. Expertise Technical knowledge and expertise of maritime logistics systems.	9. Guarantor Experts who promote a holistic view and mutual understanding of maritime logistics systems.	
<b>Source of Legitimacy</b>	10. Witness Port users.	11. Emancipation Relevant ministries or entities are open to criticism or questions from affected parties.	12. Worldview An ecosystem that promotes coordination between port users, port operators, and the government.	

interviews, the informants discussed the role of humans, technology, and systems. Furthermore, the improvement of humans is not about their problems or issues with corruption, but it is about their utilisation. The respected informants from PO said that the loss from corruption is worth less than the loss from unutilised labour in ports (represented by truck or freight transport drivers, shipping labourers, tax employees, etc.). In the causal loop diagram in Fig. 2, productivity is a factor that relates with other factors in other stakeholders such as tax revenue for the government, good corporate governance for the interactions between PO and PU, and dwelling time as the important factors. Based on the aforementioned explanation about productivity, therefore, this study identifies two main determinants of productivity: lead time and human capital.

- a. **Lead time** was mentioned as one of the port performance indicators based on several studies (Brooks, 2006; Cullinane, Song & Gray, 2002; De Monie, 1987; UNCTAD, 1976; Woo, Pettit & Beresford, 2011), in specific terms including dwelling time which had been discussed and mentioned by PO and PU in terms of its definition, especially in how to calculate and assess its performance. Dwelling time is a similar concern for both PO and PU. In the causal loop diagram, dwelling time is closely related to technology investment and productivity. More specifically, as explained before, the mentioned technology investment refers to the tracking system of the freight forwarder in the terminal as one example that influences dwelling time. In the interview with PO, there is disagreement with the definition provided by the government as an indicator to measure performance in Indonesian ports. Dwelling time is the time measured when a truck gets in the port terminal and then loads (or unloads) the logistics to (or from) the ship until it leaves the terminal, even without the process of a clean and clear permit. Due to this definition, for the sake of a shorter dwelling time, many trucks without permits were often moved out of the terminal but unable to continue to the destination and deliver their loads. The PO should make another space outside the terminal and even further from there. The definition resulted in a bad effect for PO and PU because there is an unnecessary investment for providing a temporary space for trucks which wait for a longer time than waiting for a clean and clear process in the terminal.
- b. **Human capital**, as mentioned by PO, was the priority based on the informants' perspectives to improve port performance compared to other factors, such as system and technology. Human capital as a port performance indicator is assessed qualitatively to map knowledge and skills, capabilities, training and education opportunities, as well as commitment and loyalty among human resources working in the port (Alavi, Kayworth, & Leidner, 2005; Brown et al., 2011; Kaplan & Norton, 2004; Marlow & Casaca, 2003; Wang, Haralambides, & Zhang, 2021; Woo, Pettit, & Beresford, 2013). Human capital is involved in the good corporate governance factor in the causal loop diagram.
2. **Service costs** contain the overall container loading and unloading, container handling charge, and cost of terminal service (Brooks & Schellinck, 2013; Marlow & Casaca, 2003; Woo, Pettit & Beresford, 2013), which also refers to one part of the total logistics costs that were found to be a critical goal of the development of the Motorways of the Sea Program. The total logistics costs were mentioned by all the informants frequently in the interviews, especially for all the informants who represented port operators and port users. Although the total logistics costs are broader than service costs which refer to the costs from the activities within the port, service costs are the central part of the total logistics costs in the discussions. In the interviews, PO

discussed the service costs with more details, including container loading and unloading costs when discussing the efficiency and effectiveness of the transportation mode in port facilities and infrastructure such as trains and toll roads.

3. **Intermodal transport systems** focus on the transportation strategy of the logistics from and to port facilities (AlRukaibi, AlKheder & AlMashan, 2020; Ferrari, Parola & Gattorna, 2011; Notteboom & Rodrigue, 2005; Panayides & Song, 2009; Woo, Pettit & Beresford, 2013). This terminology was mentioned by informants from PO, PU, and GR. The informants from PO stated that they had built other infrastructure besides the port, such as a toll road, to reduce congestion in transporting logistics from the port to the surrounding industrial area. It is an investment on the one hand and will improve the port service itself in the future. Meanwhile, GR and PU stated that infrastructure development to support maritime logistics should be seen as a helicopter view, focusing on the port infrastructure or shipping industries' capabilities and supporting infrastructures such as inland transportation and economic development in rural areas. They agreed that maritime logistics is broader than expected, which covers beyond the sea transportation of the logistics.
4. **Information and communication (IC) integration practices** deal specifically with how to collaborate with channel members (Albadvi, Keramati & Razmi, 2007; Kaplan & Norton, 2004; Panayides & Song, 2009, 2013; Vrakas, Chan & Thai, 2021). Informants from PO experienced that the role of the administration process should be improved to make it more efficient in the time and space of the port performance. The integrated and transparent information system and fully utilising information technology can generate more trusted and efficient bureaucracy processes. According to the PO statement, a bottleneck still can happen in the bureaucracy process since it will involve 18 or more ministries and departments in Indonesia. However, based on a suggestion from PO, the government should support IC integration practices through deliberation by authorities, not only rely on minister permits. This performance indicator refers to technology investments in the causal loop diagram and its effects on transparency and good corporate governance.

Those factors are important to be considered. This research found that productivity is the main strategy to minimise logistics costs in maritime logistics systems with infrastructure development and human-centred technology investments. Another finding is that dwelling time or port service time is the preferable way to measure port performance. However, the definition of a performance indicator should be carefully analysed as stated by the informants from PO that there is an impact of misinterpretation of the definition of an indicator such as dwelling time, especially in terms of making the indicators succeed as stated in point 2 about lead time.

#### 4.3. Maritime logistics system

The description of the stakeholders is further supported by the dynamics of the factors which deliver lower logistics costs in maritime logistics. The factors were derived from the interview results and scoping reviews. Fig. 3 depicts a causal loop diagram (CLD) representing the interrelationships between variables in the maritime logistics system. The main goal or finishing point of the causal loop diagram is higher productivity as declared by the informants of PO and PU as from their experiences in the port businesses. GR also stated that infrastructure development, including ports, increases port productivity and accessibility in Indonesia.

There are two preferred starting points to explain the CLD. It can be started from developing port facilities or infrastructure and service system investment (I&SS), including equipment and technology advancements, which will involve the government mostly with

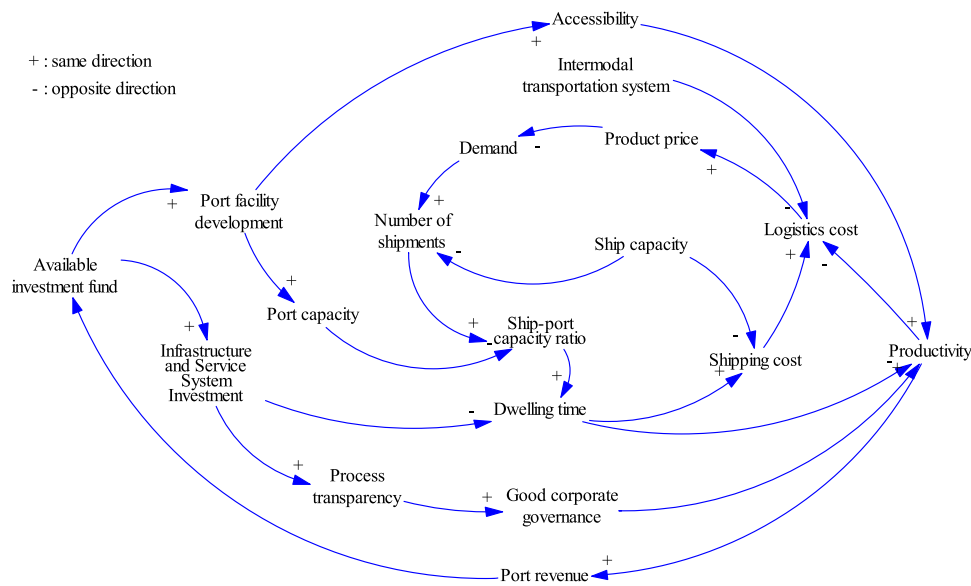


Fig. 3. Causal loop diagram of Indonesia's maritime logistics.

support from the industry and community. The underlying reasons for choosing these points are that the Indonesian government has built various infrastructure, including a port, in their current political ambition. Meanwhile, technology improvement is the primary strategy that has been adopted by PO, as stated in their interviews. The informants revealed that the service system improvements in technology such as cashless payments and a truck tracking system had contributed to the rapid enhancement of the port's operations.

The development of port facilities will increase the port capacity and accessibility. The matching port capacity and the number of shipments will result in lower dwelling time, which will deliver lower shipping costs (De Borger, Proost & Van Dender, 2008). Lower shipping costs and the availability of an intermodal transportation system will reduce the logistics costs (Han, 2018; Zaman, Vanany & Awaluddin, 2015). Furthermore, the lower logistics costs will result in lower product prices in the community. Consequently, the community will be attracted to buy more products (Langen, 2007), which will increase the number of shipments and improve the loading-unloading time. Besides port capacity, the development of port facilities also intends to develop more ports or routes in the maritime logistics system, thus, more access for products to be delivered to more places or ports (De Langen, Nijdam & van der Horst, 2007). Henceforth, a lower dwelling time and more places covered in maritime logistics indicate higher port productivity.

Nevertheless, as mentioned by the informant from PO, the lower logistics cost will not necessarily deliver a lower price if there is no contribution of the community to make their potential commodity and market. Furthermore, the role of the industry and the government in terms of product distributors is needed to maintain the prices at lower levels (Michail & Melas, 2021) and avoid irresponsible parties from getting more profit from the lower logistics cost advantages. Irresponsible behaviour has been an issue in infrastructure development, as stated by the informants from GR. The informants from GR gave an example of local governments, which often take advantage of infrastructure development. They abuse power and misuse it to intervene in the development process.

On the other hand, I&SS investment, as stated by PO, specifically in the form of cashless payments and a tracking system for the freight forwarder in the terminal, has produced a transparent

process and a shorter dwelling time. The informants from PO explained that cashless payments can give a more transparent service process and transactions between port users, port operators, and port administrators. Meanwhile, technology investments in tracking systems for the freight forwarder will give PO more control to the truck in the terminal, so it will make the loading and unloading quicker since it will avoid irresponsible truck drivers. In the end, more technology investments related to a decreased dwelling time and increased process transparency (Garg & Panchal, 2017; Mieseigha & Ogbodo, 2013) will deliver better corporate governance practices (Lam, Ng & Fu, 2013). Lower dwelling time and broader good corporate governance practices will generate more productivity in the port.

Next, productivity is by some means related to the starting point on the causal loop diagram: I&SS investment and port facility development. Productivity will influence I&SS investment and port facility development through port revenue and its effects on the available investment funds, both from the government and private funding. Higher productivity in the permit process will generate more income for the government in tax revenue (Wendler-Bosco & Nicholson, 2020). Higher productivity also will generate more funds from private companies because it can be seen as an appropriate performance indicator to seek the potential of port businesses in Indonesia. Higher performance will generate more attention to investors from the private sector in providing infrastructure and technology investments in maritime logistics, specifically the Motorways of the Sea Program.

#### 4.4. Dynamics in the maritime logistics system

As this study aims to identify the dynamics of the stakeholders' activities, which are represented as factors in affecting the maritime logistics system performance, the structure and the interrelationships among factors that have been mapped in the CLD are further expressed in mathematical models and presented graphically using a stock and flow diagram (SFD). However, there is a different scope between the CLD and SFD. The previously discussed CLD is the wider system of interest, whilst the SFD is the narrow system of interest (Daellenbach & McNickle, 2005). In other words, the CLD becomes

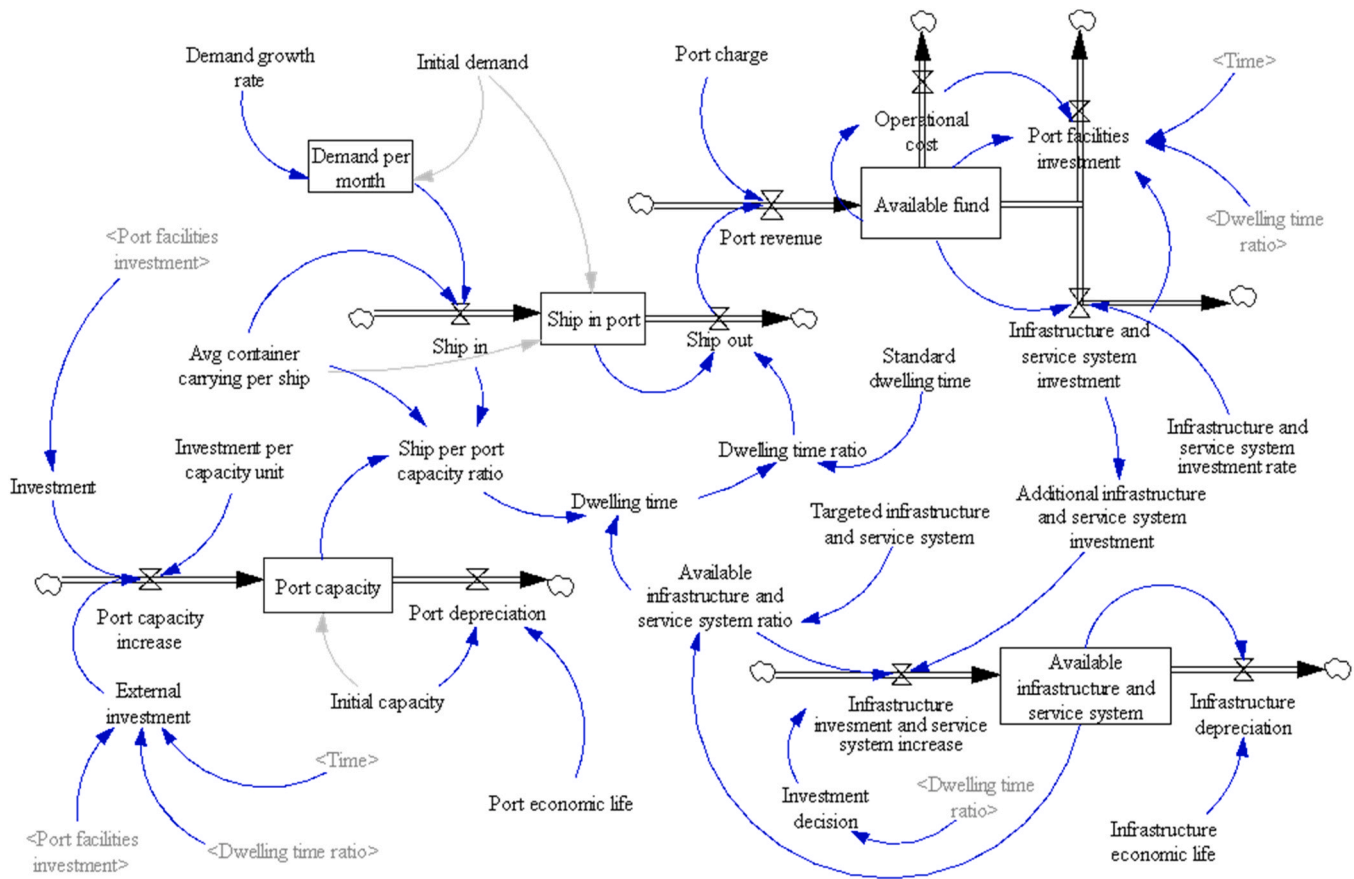


Fig. 4. Stock and flow diagram of Indonesia's port system.

the relevant environment of the SFD as the narrow system. In this case, the CLD covers Indonesia's maritime logistics system, as the SFD displayed in Fig. 4 covers Indonesia's port system. The port system is selected as the narrow system of interest as it is a fundamental element in the maritime logistics system and an essential node in intermodal transportation systems (Wendler-Bosco & Nicholson, 2020) and is used to infer the maritime logistics system (Panayides & Song, 2009).

In constructing the SFD, the included variables need to lend themselves to objective and precise measurements since they will further be simulated to capture the dynamic behaviour of the system (Bala, Arshad & Noh, 2017). The fact that not all variables in the CLD can be measured directly, such as process transparency and good corporate governance, this study decided to narrow the scope of the system so that only variables with legitimate numerical data were included in the model. The rationale behind this decision is to avoid too many assumptions in parameterisation as it may result in the model failing to represent the real system behaviours (Bala, Arshad & Noh, 2017).

The model was developed using several input parameters and stock initial values from secondary sources, such as government reports, laws, and regulations; PO annual reports; and news. A base scenario model of 200 months was run to see the behaviour of port performance indicators in the SFD as represented by the ship in port, which is a manifestation of the productivity and the dwelling time as a simplification of the lead time. Fig. 5 portrays the results of the simulation. Fig. 5(a) depicts the behaviour of the ship-in-port, as well as the ship-in and ship-out. It should be noted that the ship-in-

port represents the total number of ships served and queued at a given time. As the demand surges over time, the number of ship-in increases as well. Consequently, the number of ships in port is multiplied and forms a build-up on the 33rd month.

Similarly, as depicted in Fig. 5(b), the dwelling time graph has an uptrend. However, as can be seen from the graph, some kind of force bends down the increasing rate of the dwelling time. It makes the graph almost resemble the square root function graph. This research found that the rapid increase in the dwelling time at the beginning period was then inhibited by continuous improvements in the port infrastructure and service system (I&SS), as the dwelling time exceeds the standard dwelling time. The increasing demand that consequently increases the revenue results in more funding invested to advance the port I&SS. Additionally, the port facility investment accelerates the dwelling time reduction as portrayed in the 72nd, 132nd, and 192nd months.

The port facility investment was modelled to be added every five years from the available fund only if the available infrastructure is insufficient to keep the dwelling time less or equal to the set standard. It is also assumed that there is a delay between the investment and the increase of port capacity. Nonetheless, the dwelling time curve goes up again along with the increased demand.

#### 4.4.1. Model validity and sensitivity analysis

To validate the dynamic behaviour of Indonesia's maritime logistics system modelled, the simulation results of the model should be compared with the real processes (Vlachos, Iakovou & Xanthopoulos, 2007). This measure was carried out in the present



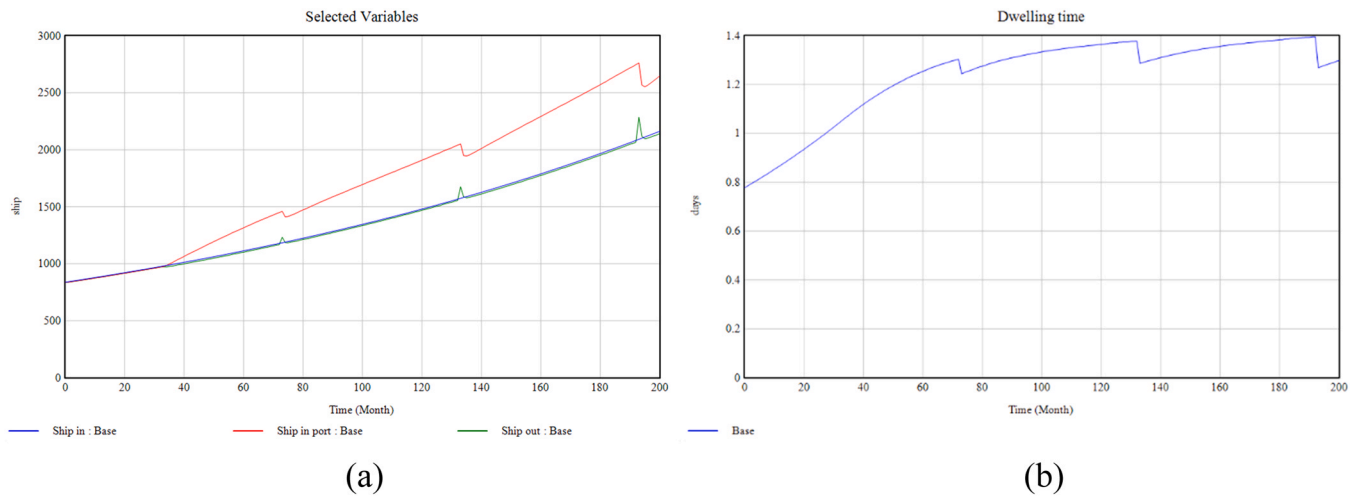


Fig. 5. Base scenario model results.

study by ratifying the simulation results with the informants and testing the model to the historical data of Indonesia's port throughput data from 2010 to 2019, as derived from UNCTAD. Since the model used the number of ships rather than the twenty-foot equivalent unit (TEU) whilst the historical data was recorded in TEU, the average container carrying capacity (TEU) per container ship was used to convert the measures into the number of annual ship-out. The results indicate that the model is considered a good representation with an approximate 7% range of error. The measures used were %MAE, %RMSE, and MAPE. (Gilliland, 2010, pp. 1).

Furthermore, a sensitivity analysis was carried out to identify the most accountable factor in determining the port performance and the system's behaviour. The selected changing variables in conducting a sensitivity analysis were demand growth rate, I&SS investment rate, and port charge as they are dynamically changing and impact the port performance. The demand growth rate was selected as it determines through the demand per month the port productivity (Wong, Ling & Zhang, 2021; Xu et al., 2021), which is represented by the number of ships in port. Additionally, a change in

demand is one of the characteristics that ship liners, as the PU, need to cope with to be resilient (Wong, Ling & Zhang, 2021). The I&SS investment rate was also included as a changing variable since it influences the acceleration of the available I&SS, such as equipment and technology, to enhance the port productivity (Lin, Yan & Wang, 2019), in this case, through the dwelling time deduction. Moreover, this variable is under the full authority of the port operators (PO). Notwithstanding the effects of the I&SS investment rate on the port productivity, the I&SS buildout depends upon the amount of money available to be invested. Thus, the port charge is considered as a changing variable as well since the available funds are contingent on it, and in turn, it manifests the port performance (Ha, Yang & Lam, 2019). Furthermore, the government (GR) is involved in regulating the variable.

A sensitivity analysis was conducted using the ceteris-paribus principle. The sensitivity analysis results are depicted in Fig. 6.

The results indicate that the changing variable that has the most significant impact on dwelling time is the port charge. A higher port charge results in higher revenue which also means a more

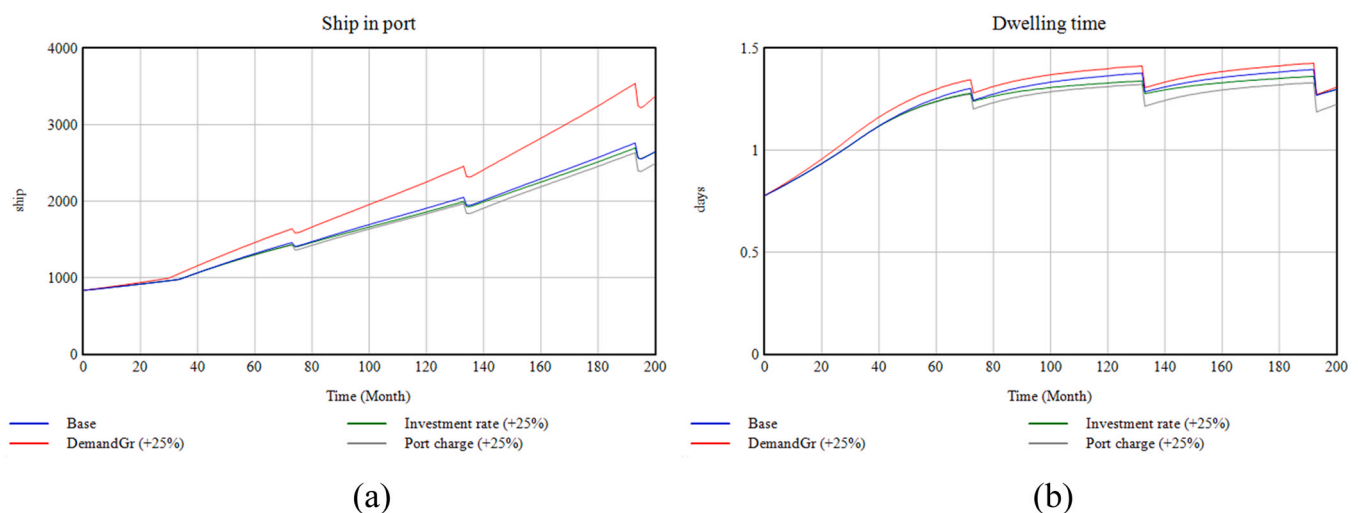


Fig. 6. Sensitivity analysis results.



**Table 5**  
Scenario description.

Scenario No.	Scenario Name	Description
Scenario 0	Base	Self-funding for both I&SS and port facility investments using the available funds.
Scenario 1	No port investment	Available funds only allocated for operational costs and I&SS investment.
Scenario 2	Fully funded externally	The port facility investment is funded by an external entity, e.g., the government.
Scenario 3	Co-funding investment	The port facility investment is funded by internal (from the available fund) and external funding sources, with a proportion of 51:49.
Scenario 4	No I&SS investment	No infrastructure and service system investment allocated.

considerable amount of funds invested in improving the port I&SS. Thus, it is the available I&SS that has a critical role in reducing dwelling time.

The second most accountable variable in determining dwelling time is the demand growth rate. Consequently, the stakeholders must anticipate the demand volatility, for instance, by adding the amount of port I&SS investment to keep the dwelling time below the standard, especially given the possible swings of demand growth rate up to 100% according to the historical data. Nonetheless, among other changing variables, the change in demand growth rate causes the largest deviation in the ship-in-port variable, representing the port performance in this study. The influence of the port change follows it.

The least accounted variable in affecting change in both dwelling time and ship-in-port is the investment in I&SS rate. The other two variables dominate the investment in the I&SS rate because the absolute value of this variable is considerably small (with an initial value of 0.1293). A value change of 25% from a variable becomes meaningless compared to the value change of the port charge and demand growth rate. Apart from that, interestingly, it seems contradictory with the previously mentioned finding that concludes a port charge has a significant impact on productivity because it is related to the I&SS enhancement. Therefore, further scrutiny regarding the importance of I&SS investment is carried out in the next section.

#### 4.4.2. Scenario analysis

According to the base scenario and sensitivity analysis results, it is known that the dwelling time depends on the port capacity and I&SS availability. To accelerate the dwelling time, both the port capacity and I&SS availability should be improved. Thus, the amount of funds invested in such accounts is a determinant factor as well. Four scenarios are considered in this study to explore the effects of the amount of funds invested and its allocations, as summarised in Table 5.

These four scenarios were selected based on the existing or possible conditions. According to the statements from PO and PU, the underlying reasons in considering Scenarios 1 and 2 are related to market development in the port area. There is a potential risk of no port facility investment, which is represented by Scenario 1 due to the lack of market development in the port area that creates no attraction for other parties to invest. In contrast, in the area where the market developed rapidly, there is a trend for the government to invest in the port facility expansion without any contributions from the private sector.

Scenario 3 was based on the current condition, where private companies interested in partnering with PO develop port facilities, in line with a study conducted by Nyman et al. (2020). Lastly, Scenario 4 represents the current situation where the fund to improve I&SS was budgeted but not allocated effectively. Consequently, there is no upgrading in I&SS. Such a situation is assumed to be similar, with no I&SS investment allocated.

After simulating all the stated scenarios, the results are depicted in Fig. 7. To accurately assess the port performance, a ship build-up graph was also constructed. It represents the number of ships in port that have not been served in any given month. In Scenario 1, it can be seen that the dwelling time behaviour of this scenario approximates the behaviour of the dwelling time in the base scenario. The main difference is that the dwelling time in Scenario 1 constantly increases.

Similarly, the ship-in-port of this scenario continuously increases the build-ups. In contrast to Scenario 1, the dwelling time in Scenario 2 speeded up significantly after the first port expansion. It results in a reduction in the number of build-up ships in port. Investing in port facilities improves the capacity of the port. As a consequence, more ships can enter the port. The Scenario 3 results do not deviate much from the base scenario results. Despite the additional funding source to invest in the port facilities, the expansion does not significantly reduce the dwelling time. It is due to the amount of external funding being limited by the regulation (must not exceed 49% of the total investment). The most compelling finding from this analysis is that when there is no monthly investment in I&SS, both the dwelling time and ship build-up are increased exponentially, as seen in the Scenario 4 results. It indicates that I&SS is the most accountable factor in determining the port performance.

As aforementioned in the sensitivity analysis results, the I&SS investment rate has the least impact on the dwelling time and ship-in-port variables. Interestingly, when the I&SS investment rate is set to be 0, or no I&SS investment, the values of dwelling time, ship-in-port, as well as ship build-ups exponentiate remarkably. The only thing that slows them down is the port facility expansion. Nonetheless, this expansion only holds the surge of ship-in-port and ship build-up for short periods. The impact is also similar for the dwelling time.

Given these points, it is known that the availability of I&SS has the most critical role in determining port performances. The I&SS covers both physical and non-physical infrastructures that enable PO to deliver its services. These include the technological system applied, administration procedures (Albadvi, Keramati & Razmi, 2007), human capital that supports the service system (Brooks & Schellinck, 2013; Brooks, 2006), and the interconnectedness between the port and land logistics system (AlRukaibi, AlKheder & AlMashan, 2020). It could also be why scenarios related to the port capacity (Scenarios 1–3) are dominated by the scenario connected to the availability of I&SS (Scenario 4).

Moreover, these findings are supported by the facts mentioned by the stakeholders involved in this study as informants. An IC system that integrates stakeholders to deliver the service seamlessly has been built in the current condition. However, it has no significant impact on improving the port performance. One of the reasons is because the human capital has not been prepared to use it. Some of the entities involved are still reluctant to use this integrated system. Therefore, deliberation and synergy among stakeholders are required. It is another challenge that needs to be solved to improve

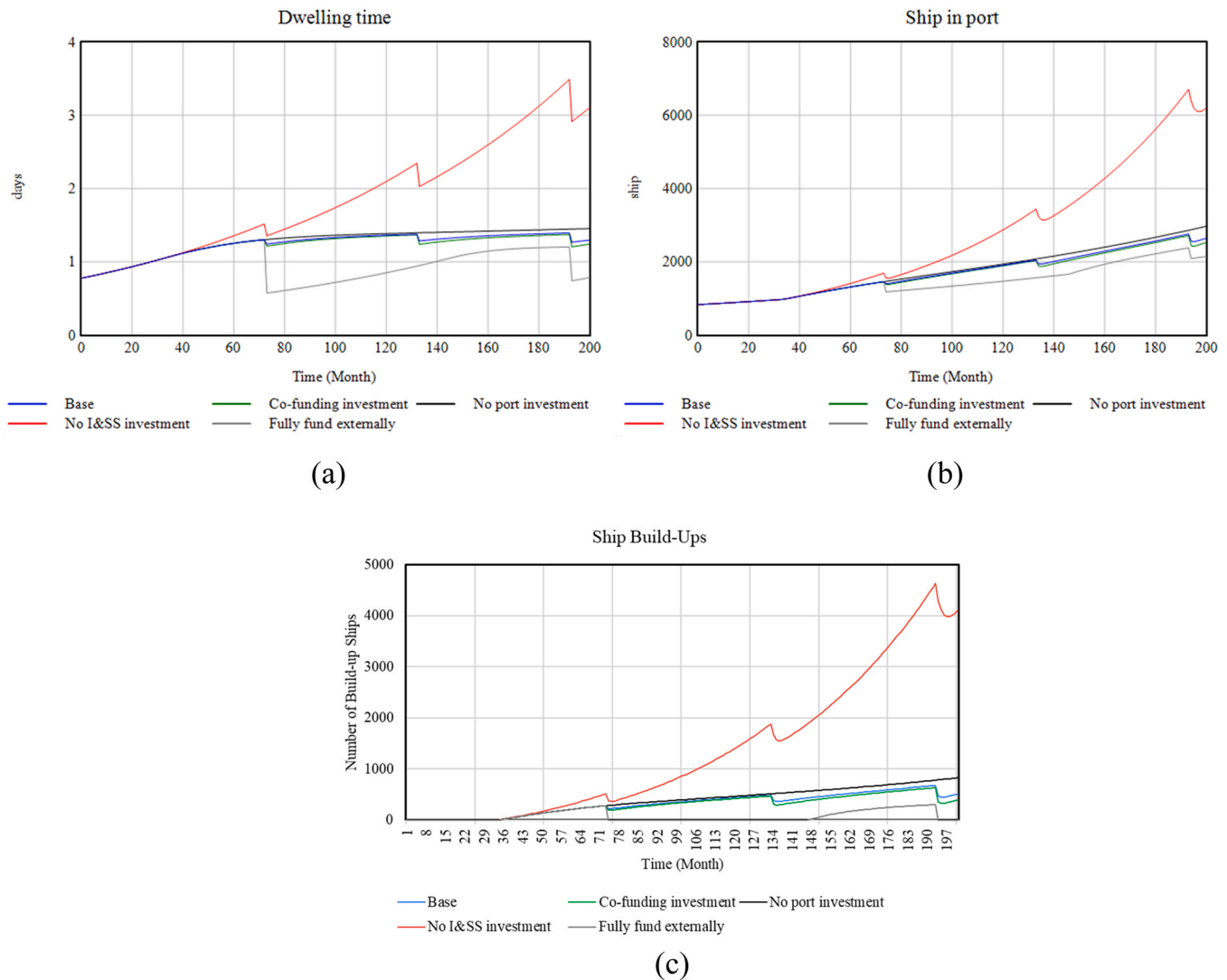


Fig. 7. Scenario analysis results.

port performance. Nonetheless, these facts highlight that it is not only the infrastructure that is a determinant but also the service system that involves human capital (Wang, Haralambides, & Zhang, 2021).

## 5. Conclusion

Seeing the importance of maritime logistics in Indonesia, there is an urgency to build a comprehensive maritime logistics system; thus, this study constructed a maritime logistics system based on stakeholders' perspectives and retrieved parameters or variables that could significantly affect the system itself.

Interviews with three major actors in the systems (port operator, port users, and port administrator) have resulted in the emergence of three other important parties which are the local government, industries (product distributors and commodity suppliers), and the broader community as potential customers. These stakeholders relate to each other by affecting one another, asserting intervention, or establishing collaboration. Hence, policy interventions to design a policy implementation of the Motorways of the Sea Program should be generated from the shared values among stakeholders.

To generate optimal recommendations, a causal loop diagram was also utilised to identify the port performance indicators. There were four important factors discovered about maritime logistics

systems: productivity that includes lead time and human capital; service costs; intermodal transport systems; and information & communication (IC) integration practices. By inserting policy interventions that can optimise these factors, it can lead to a more effective system.

Based on the simulation results, infrastructure and service system (I&SS) was found to be the most accountable factor in determining the dwelling time and productivity which was indicated by the ship build-ups. The I&SS covers both physical and non-physical infrastructure, including information and communication technology, service procedures, and human capital that support the service system. However, building the I&SS should be geared up by a policy to support fair collaboration, especially between the government and potential investors from the local private sector such as companies that have a role as port users and port operators. Fair collaboration means that the potential market in the port can match with the investment cost needed to build and develop the port.

This study found that port performance is also sensitive to the demand change. Hence, it is suggested to increase the market potential of the port location where infrastructures are built as stated by port operators as well. This is done so that the port becomes an attractive destination. It is necessary to gradually increase the number of distributors of goods and economic activities in the community through collaboration and contributions from the local

government and potential industries in order to expand the potential market. In addition, collaborations can also be carried out with port users in providing opportunities to invest in infrastructure development. In essence, the management of the port itself cannot only focus on providing services within the port but also improving the economic capacity of the surrounding community, so that they are able to produce quality products that can become commodities to fill the void of ships when they return to their original location.

Another recommendation is to have capable and compatible human capital to deal with the operational and administrative tasks in ports to increase productivity and decrease lead time, hence decreasing logistics costs. Finally, linking intermodal transport from port to land and vice versa is required. This policy needs to be implemented on a national level to open more access between ports and land. Further research should be conducted to analyse the most optimal solutions to increase productivity and benefit all stakeholders.

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### Credit authorship contribution statement

**Yos Sunitiyoso:** Funding acquisition, Conceptualization, Methodology, Investigation, Supervision, Writing – original draft, Writing – review & editing. **Shimaditya Nuraeni:** Conceptualization, Investigation, Project administration, Writing – original draft. **Noorhan Firdaus Pambudi:** Conceptualization, Resources, Investigation, Writing – original draft. **Tutik Inayati:** Conceptualization, Methodology, Software, Investigation, Writing – original draft. **Ilham Fadhil Nurdayat:** Conceptualization, Software, Investigation, Writing – original draft. **Fikri Hadiansyah:** Conceptualization, Data curation, Investigation, Writing – original draft. **Adhya Rare Tiara:** Conceptualization, Data curation, Software, Visualization, Writing – original draft.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Appendix

#### Interview Guidelines & Questions List (Critical System Heuristics Approach)

Each of the stakeholders in the Indonesian Motorways of the Sea ecosystem should be reminded to respond towards each of the following questions (NOTE: the objectives of the questions are (i) the implementation of the Motorways of the Sea, OR (ii) the efficiency of the Motorways of the Sea).

#### Source of Motivation

1. Who is the intended beneficiary of the implementation and/or efficiency of the Motorways of the Sea?

2. What is the purpose of the development of the Motorways of the Sea?
3. What are the possible benefits of the development of the Motorways of the Sea?

#### Source of Control

1. Who is/are the decision maker(s) regarding the implementation and/or efficiency of the Motorways of the Sea?
2. What are the conditions of the successful planning, implementation, and/ or efficiency of the Motorways of the Sea?
3. What conditions are outside the control of the decision-maker?

#### Source of Knowledge

1. Who provides the relevant knowledge and skills for the implementation and/or efficiency of the Motorways of the Sea?
2. What are the relevant new knowledge and skills for the implementation and/or efficiency of the Motorways of the Sea?
3. Who is regarded as an assurance of the successful implementation and/or efficiency of the Motorways of the Sea?

#### Source of Legitimacy

1. Who represents the interests of those negatively affected by the implementation of the Motorways of the Sea?
2. What are the opportunities for the interests of those negatively affected to have an expression and freedom of implementation of the Motorways of the Sea?
3. What space is available for reconciling differing worldviews regarding the implementation of the Motorways of the Sea?

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