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Cruise terminal operational evaluation from an environmental, social, and governance perspective using a system dynamics approach

Anak Agung Bagus Dinariyana[1,2*], Dhimas Widhi Handani[1], I Gde Manik Sukanegara Adhita[1], Fadilla Indrayuni Prastyasari[1], Kadek Putra Puja Wirawan[1]

[1]*Department of Marine Engineering, Institut Teknologi Sepuluh Nopember (ITS), Indonesia*.
[2]*Interdisciplinary School of Management and Technology, Institut Teknologi Sepuluh Nopember (ITS), Indonesia*.

Corresponding author: Anak Agung Bagus Dinariyana (*Email: kojex@its.ac.id*)

Abstract

The number of international tourists visiting Bali by cruise ships is increasing annually. In response, the government started a project to enhance services at the Port of Benoa cruise terminal, considering not just infrastructure but also environmental, social, and governance (ESG) aspects that impact terminal service performance. ESG assessments can be classified into various factors, particularly within the dynamic operations of terminal services. Understanding these factors and their relationships is vital for assessing the impact of ESG on terminal performance. Service performance is measured by passenger embarkation and debarkation durations, with operational efficiency playing a key role in streamlining these processes. Subsequently, a system dynamics model is employed, and a model is developed considering ESG factors such as energy consumption (environment), air pollution (environment), port governance score (governance), and employee satisfaction index (social). The findings indicate that these factors positively contribute to the efficiency of terminal port operations. In scenarios of improvement, the service time can be reduced to 2.94 hours to serve 1,636 passengers, compared to 3.02 hours for 1,402 passengers without improvement. Therefore, the simulation results show that installing onshore connections, offering employee financial compensation, and implementing management improvements will enhance terminal operations.

Keywords: Air pollution, Employee satisfaction index, Energy consumption, Port governance score, Port performance, System dynamics.

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1. Introduction

The demand for cruise ships keeps rising annually. In 2023, global figures reached 31.7 million passengers, a 6.8% increase from 2019 [1]. This escalating demand was reflected at the port of Benoa, which welcomed 48 cruise ships carrying 39,600 passengers during the same year [2]. The increase in visits led to the development of the port area through the Bali Maritime Tourism Hub (BMTH) initiative, aiming to boost ship calls by 1.5 times by 2027 [3]. This port development caters specifically to the requirements of cruise ships, focusing on both port infrastructure and tourist experiences [4]. Investments in areas for receiving cruise ships typically emphasize port facilities [5], passenger satisfaction [6, 7], and fostering relationships with neighboring regions [5]. The development of ports can rely on the existing performance of their terminals. Nevertheless, assessments of cruise ship terminal performance are uncommon, contrasting with the steadily expanding cruise market [8]. Typically, performance evaluations target commodity-handling ports, such as those dealing with containers [9], liquid bulk, and dry bulk cargo [10]. These evaluations can encompass various factors, including environmental [11], social [12], and economic [13] dimensions, as well as the integration of all three [14]. Such evaluations play a critical role in the operations of cruise terminals, particularly with a focus on sustainability [15].

Environmental, Social, and Governance (ESG) has become an influential framework for evaluating port operations. The ESG concept is a method for assessing corporate sustainability through ESG performance indicators [16]. ESG assessments investigate environmental impacts, social influences, and governance models [17]. The objectives of each ESG assessment component lie in providing strategic and tactical benefits to companies, leading operational management and port policies to begin implementing ESG for improved port performance efficiency [18]. However, ESG assessments in the context of port operations are relatively rare, with most evaluations being qualitative rather than quantitative [17]. Various models can be used to conduct ESG assessments, including semantic network analysis [19], ESG scoring method [17], and system dynamics [18].

Among various modeling approaches for service operations in port terminals, system dynamics is a viable method to map service-related variables, particularly in the context of ESG assessments. The system dynamics approach aims to identify factors influencing system behavior while enhancing the understanding of complex and dynamic changes [20]. System dynamics facilitates model formulation, simulation of dynamic behavior, policy evaluation, and recommendations for improved policies and implementation [21]. This modeling approach has been previously applied to optimize port areas, such as implementing new strategies [22] or analyzing the impact of new policy applications at ports [23]. By illustrating the relationships between variables, system dynamics enables the identification and resolution of issues within the system by adjusting parameters representing the system's success [21].

System dynamics, as a modeling method capable of mapping relationships between variables within a system, is a suitable approach for assessing the performance of cruise ship terminals based on ESG standards. ESG assessments using system dynamics have previously been conducted for container terminals [18]. Unlike container terminals, which tend to have more regular ship arrivals, cruise ship terminals have dynamic scheduling. Cruise ship arrivals are generally influenced by tourist demand and destination attractions in the target area [24, 25]. Terminal services, as one of the factors influencing cruise ship arrivals, underscore the importance of understanding the current and future service performance. The performance assessment and simulation are then conducted using the system dynamics method based on ESG evaluation standards. The variables involved in the assessment are determined through observations and interviews at the Port of Benoa Cruise Terminal, as well as variables related to ESG.

2. Literature Review

There is no standard definition of ESG; however, it is considered one of the methods for measuring a company's governance or management performance based on sustainability factors such as environmental, social, and governance issues. ESG has emerged as a vital element of corporate social responsibility and sustainability [26]. ESG is starting to be known as one of the investment aspects that assesses a company's sustainability in the future [27]. Over the past two decades, ESG has become an essential consideration in determining strategies, regulations, and policies carried out by companies by considering social and environmental factors. ESG can generally be interpreted as a broad series of environmental, social, and corporate governance considerations that can impact a company's sustainability in carrying out its business strategy in the long term [28]. ESG measurements encompass various aspects of a company's performance that are not reflected in financial reports. Financial documents fail to give management insights about reputation, quality, brand equity, safety, corporate culture, strategy, and other critical assets [29]. ESG indicators will improve the transparency of non-financial information concerning environmental, social, and corporate governance. This will facilitate the assessment of management capabilities and minimize risk [30].

A significant amount of research related to ESG has been conducted to measure operational performance at ports and to introduce maritime practices policies. Kurniawan et al. [18] have conducted research that integrates ESG assessment as a basis for evaluating the performance of container terminals through a system dynamics approach, specifically focusing on the Indonesia Port Corporation in Jakarta. The ESG factors are relevant to measuring container terminal performance, especially regarding berthing time, as the three ESG factors significantly affect berthing speed at the terminal. Sustainable development of the port economy, based on connected smart sensors and System Dynamics, is introduced by Xiu and Zhao [21]. The results obtained after conducting model simulations for the next 20 years found that the increase in the employee population and employment ratio and exhaust emissions decreased after 2025, while resource utilization increased by 80.01%. The study results determine the strategy for port management and sustainable port economic development. The design of a new maritime policy can also be integrated with an ESG performance approach [16]. Estonia's new maritime policy framework was developed by considering the drivers of finance, insurance, regulators, and consumers related to ESG. ESG performance evaluations on European international ports found that clustering three hub ports Santos, Bremen/Bremerhaven, and Barcelona from an ESG perspective could support responsible investment in the port industry [17]. The ESG framework in China's port industry assesses port sustainability through environmental, social, and governance. Among these dimensions, social responsibility is crucial for evaluating the sustainability of port operations [31, 32]. In monitoring port activities, ESG serves as vital information for evaluating ports.

At cruise terminals, responding to the global cruise industry's growth hinges on port governance and operators [32]. It's essential not only to provide adequate facilities for cruise ship passengers, but also to manage and administer the reception of cruise ships. Port governance, operators, and branding strategies are vital for developing ports for cruise ship reception. Ports focused solely on receiving cruise ships must align services with company standards [33]. Cruise ship companies prioritize not just passenger transport, but also the needs of passengers. Thus, efficiently handling passengers and goods is crucial [4]. ESG assessment is widely used for sustainability and investment information in port terminals. Typically, it produces recommendations for port terminal governance to support sustainability and enhance port performance. Kurniawan et al. [18] integrated ESG assessment in port terminals with system dynamics. Most other studies utilize one of these methods to evaluate port terminal performance.

3. Methodology and Model Development

3.1. Main Idea of ESG and System Dynamics Approach

ESG has become one of the guiding principles of responsible investment. Since 2019, ESG has gained attention as a new standard for global companies to conduct their business competitively [19]. Various companies worldwide are adopting ESG to attract investment by demonstrating their commitment to environmental, social, and governance. This also applies to the port sector, where several studies, such as those by Kurniawan et al. [18] and Dos Santos and Pereira [17] have assessed ESG performance in port operations.

ESG evaluates its components within the context of existing systems in a company. The system dynamics approach can be utilized to model these existing systems. System dynamics, including transportation and port systems, has been widely used for system modeling. For example, Fernández-Gámez et al. [14] applied system dynamics to simulate system behavior in cruise port operations related to passenger supply and demand and conducted scenario analyses on the system. Similarly, Lin et al. [22] employed system dynamics to analyze strategies to reduce congestion in port areas.

Operations within port terminal services are among the systems amenable to modeling through the system dynamics approach. Simultaneously, the sustainability of these operational systems can be evaluated using ESG. This allows the simulation of ESG components within the system dynamics model to observe how ESG conditions develop over the simulation period. The results of these simulations can then serve as a strategic tool at the management level to uphold the sustainability of port terminal operations.

3.2. Data Collection and Determination of Variables

The performance variable data used in this study is adjusted according to the cruise terminal conditions during cruise ship operations in 2023. Terminal performance will be depicted using data on embarkation and debarkation times for cruise passengers. Meanwhile, data such as the number of passengers and luggage/baggage will be used as variables that affect embarkation and debarkation times, or the terminal's performance. These four variables will be linked to the variables related to the ESG assessment. The variables included in the ESG assessment are oil pollution (environment), garbage (environment), air pollution (environment), energy consumption (environment), employee satisfaction index (social), and governance score (governance). Data for these variables were obtained through several methods, including direct interviews and questionnaires, literature studies, and direct observations. The current values for these variables are listed in Table 1.

Table 1.
Performance variables data

Variable	Average	Unit
Debarkation time	2.60	hours/ship
Embarkation time	3.40	hours/ship
Total passenger	826	person/ship
Total luggage	2135	luggage/ship
Oil pollution (environment)	8.57	kg/ship
Garbage (environment)	102.86	kg/ship
Air pollution (environment)	179.51	CO_2 ton/ship
Energy consumption (environment)	471.48	kW/service hours
Employee satisfaction Index (social)	92.80	index
Governance score (governance)	90.47	index

The main performance variables are linked to activities during cruise ship operations at the terminal. Key activities include the debarkation/embarkation rate for passengers and luggage, which indicates how many people and bags are processed per hour. These activities impact passenger embarkation, debarkation times, and other operational data such as working hours and docking times. Table 2 shows real data on these activities.

Table 2.
Passenger service activity data

Variable	Average	Unit
Debarkation rate person	937	Person
Embarkation rate person	919	Person
Debarkation rate luggage	1,500	Unit
Embarkation rate luggage	1,460	Unit
Working time	11.60	Hours
Berthing time	23.21	Hours

3.3. System Dynamics Modeling

A causal loop diagram is one stage in system modeling using systems dynamics. The data previously obtained will then be modeled into a basic model for each variable. These variables are linked to one another to understand how each one influences the others. Before computational modeling, a conceptual model is created from these variables. A conceptual model is needed as the basis for computational simulation, and its creation requires comparison with previously developed models to explain the rationale behind the relationships between the variables [34]. The conceptual model is built by defining each variable quantitatively, identifying key variables influenced by others, and establishing cause-and-effect relationships between the selected variables. The final step is to add feedback loops, indicating whether the relationship between variables has a positive (+) or negative (-) effect. This feedback helps clarify the interaction between variables in the model. A causal loop diagram for the cruise terminal operations for the port of Benoa Cruise Terminal is given in Figure 1.

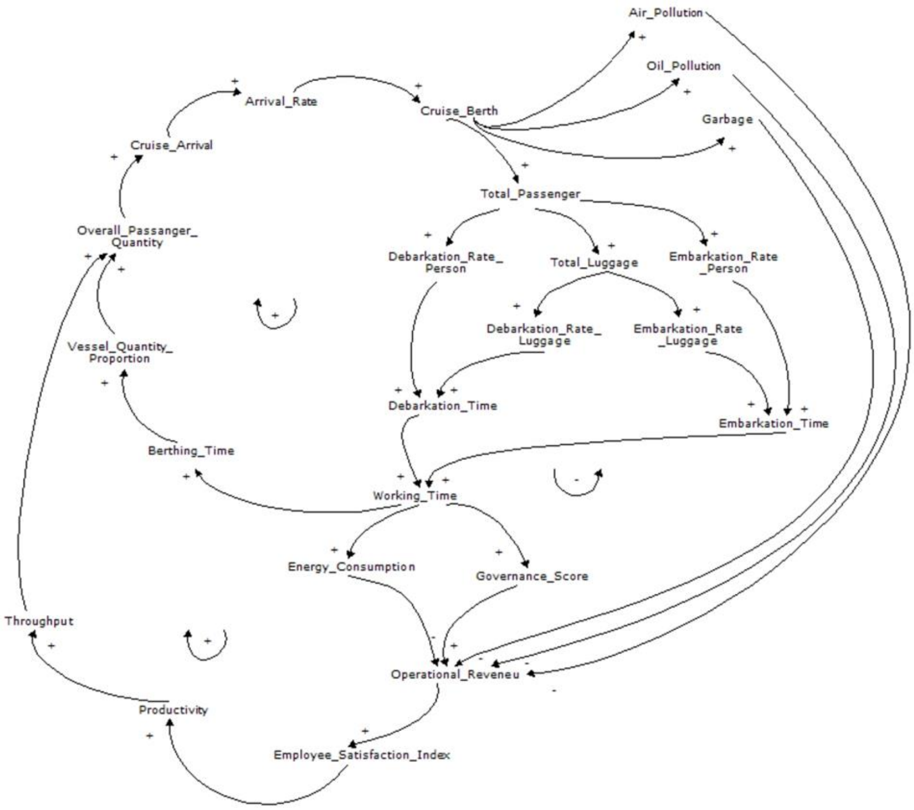

Figure 1.
Causal loop diagram for the cruise terminal operations.

In the passenger service model at the cruise terminal, the variables of debarkation and embarkation times are dynamic and represent the performance indicators of terminal service. Other variables influence these performance variables and have interrelationships that can be classified as positive or negative. These relationships are identified at the end of the arrows connecting the variables, where positive (+) and negative (-) signs are used. A positive sign means that the influencing variable increases the value of the affected variable. In contrast, a negative sign indicates that the influencing variable decreases the value of the affected variable at the end of the arrow.

3.4. Stock Flow Diagram Arrangement

The development of the performance assessment model for the terminal, considering the ESG evaluation modeled in the causal loop diagram, is followed by creating a stock flow diagram. Before adding scenarios to the model, a baseline model representing the current terminal service system is first developed. This model consists of the accumulation of variables that influence each other. The main variables, including debarkation and embarkation times, governance score, employee satisfaction index, and emissions from cruise ship activities at the port, are dynamic variables that change over time. The selection of variables for the model is based on observations of activities conducted during services at the terminal, supported by interviews with terminal staff and literature related to the system dynamics approach in port services.

This study's stock flow diagram modeling uses Powersim Software [35], where the model is built based on the previously developed causal loop diagram. Powersim Studio is a system dynamics modeling software with several tools to assist in system modeling, such as level, auxiliary, constant, link, and flow rate. These tools are arranged according to their relationships in the causal loop diagram. They are operated using functions like IF, OR, AND, and mathematical operations, depending on the nature of the system modeled to reflect real conditions. In this study, the real operational condition is the passenger service system at the terminal. The initial model represents the system as it operates, specifically during 2023. Figure 2 shows the broad modeling for the usual service scenario at the international terminal.

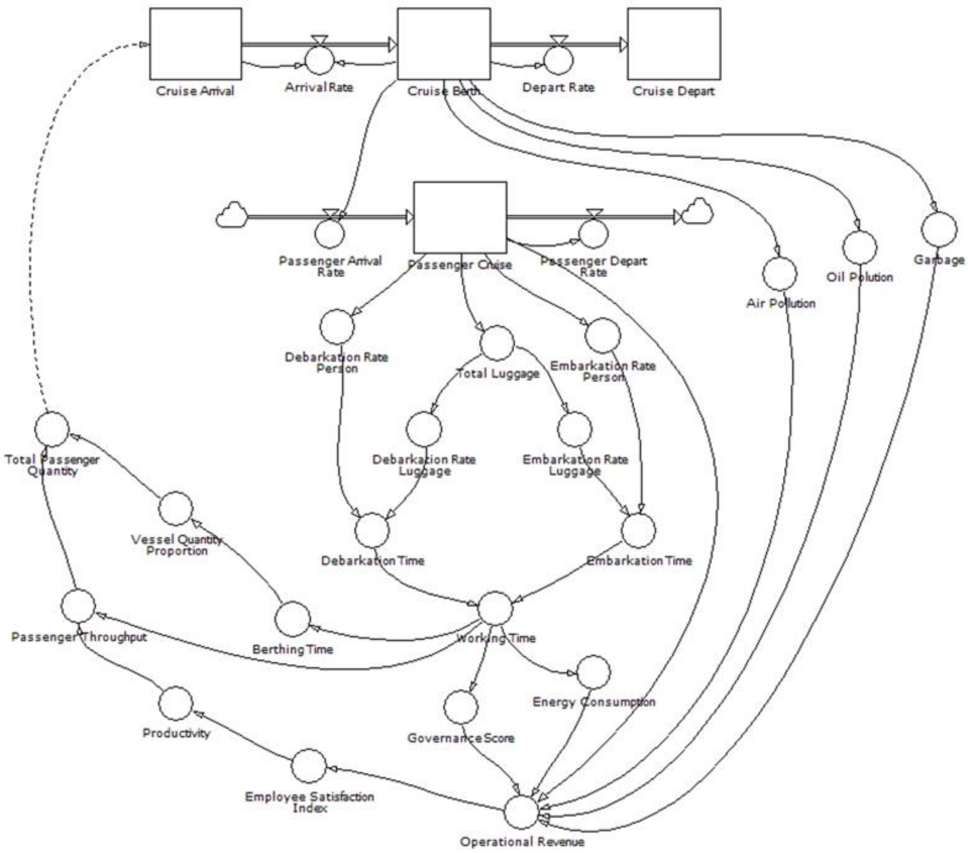

Figure 2.
Stock flow diagram for baseline simulation.

Figure 2 outlines the passenger service process at the cruise terminal, including ship docking, disembarkation, embarkation, and ship departure. The stock flow diagram models port services over one year, starting when a ship docks. Each ship disembarks a varying number of passengers. Passenger arrival rates affect the stock of cruise passengers, which decreases based on departure rates. The number of passengers at the international terminal impacts disembarkation and embarkation services; an increase in passengers extends service times. The simultaneous processing of passengers and goods establishes benchmark times based on the longest requirements from these activities.

Disembarkation and embarkation times inform terminal employees' effective working time, modeled as variables. Effective working time equals the sum of both times since cruise services begin with disembarkation and continue until passenger re-embarkation according to the ship's schedule. This working time influences ESG assessment variables, including the governance score and energy consumption. Terminal services generate operational revenue, influenced by environmental factors from ESG, such as energy use, waste, oil pollution, and air pollution, all correlated with the number of docked cruise ships.

Operational revenue impacts the employee satisfaction index, which is crucial for service development and employee growth. Consequently, the employee satisfaction index affects productivity, representing how many passengers can be effectively served by an employee per cruise. The passenger count served impacts the passenger throughput variable, indicating total service capacity for each docking. Effective passenger service time also affects berthing time for cruise ships at the terminal, where embarkation time is critical for turnover. Delays can lead to schedule adjustments, thereby affecting operational efficiency. The berthing time variable influences the proportion of the yearly vessel quantity at the cruise terminal. Multiplying passenger throughput by the vessel quantity proportion yields the total passenger quantity variable for the cruise terminal within a year. Finally, the model simulates the arrival and departure rates, reflecting cruise ship traffic at the port of Benoa, which is influenced by the previous year's passenger totals and service variables.

3.5. Model Verification and Validation

The model developed according to the concept and real conditions must be verified to accurately represent the system. Verification is also performed to ensure the issues displayed in the conceptual model are reasonable and accountable. Several verification methods are employed to ensure the model runs correctly: dimensional consistency test, extreme condition test, and sensitivity testing. The dimensional consistency test checks the consistency of each dimension in the model, including level, constant, auxiliary, and stock. The test uses Powersim Studio software, with the verification feature running automatically. Indicators such as formulation and the relationships between variables' errors are provided. If neither of these indicators is present, the model is considered verified. The extreme condition test assesses whether the model yields consistent results when faced with extreme values. Its objective is to evaluate the model's performance under such conditions.

3.6. Scenarios Given to the Developed Model

The scenario analysis is conducted to understand and provide policy recommendations for services at the terminal that are in line with anticipated developments and to achieve the targets set by the government. Scenario simulations will assist port management in preparing policies that align with upcoming changes and help anticipate the worst-case scenarios based on the considered scenarios. Additionally, the simulated scenarios will aid in selecting solutions suitable for the existing service system at the cruise terminal. The scenarios are simulated by adding or modifying variables in the previously established baseline model. Model adjustments align with the scenario being tested, and all scenarios will be run simultaneously according to the rules and policies for developing the port of Benoa. Five scenarios are simulated in the base model.

3.6.1. Scenario 1: BMTH Development

The BMTH development project aimed to transform Benoa's port into an integrated tourist destination. The development of BMTH is motivated by several factors, including the absence of a home port for international cruise ships or yachts in Indonesia, the strategic location of Bali for tourism development, the high number of cruise ship and yacht visits at the cruise terminal (the highest in Indonesia), and the proximity of the terminal to Ngurah Rai airport and the Bali Mandara toll road [3]. The BMTH development is expected to increase the number of cruise ship and yacht visits, enhance the quality of local products, and provide additional entry points for tourists into Indonesia.

Once the development is completed, BMTH will significantly influence the sustainability of cruise ship services at the terminal. The optimal operation of BMTH is projected to begin in early 2027. Cruise ship arrivals and foreign tourist numbers in 2027 may increase by up to 1.5 times compared to current projections. This increase in tourists will affect how port management handles passenger services at the international terminal. In this scenario, three variables are affected: cruise berth, passenger cruise, and working time.

3.6.2. Scenario 2: Reducing CO_2 Emissions by Adding Onshore Connections

The policies issued by the government form the basis for the second scenario in this study. Presidential Regulation No. 98 of 2021, which addresses implementing carbon economic value to achieve national contribution targets and greenhouse gas emission control in national development, is one such regulation. Greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), can increase the Earth's surface temperature and affect climate change if these gases accumulate excessively in the atmosphere [36]. Indonesia has set a target for reducing greenhouse gas emissions by 29% to 41%, with the 29% reduction achievable through domestic efforts.

At the cruise terminal, implementing an onshore connection is the appropriate method to reduce emissions from cruise ships. This is due to the port's proximity to the FSRU Karunia Dewata and a gas-powered power plant, making the electricity supplied to the ship cleaner than the generators on the cruise ships. Using onshore connections with cold ironing technology and power plants using LNG as an energy source can reduce CO2 emissions by up to 40% and lower other contaminants, such as SOx, to their lowest levels [37]. Based on these emission reduction efforts, a simulation is conducted to assess how adding onshore connections can reduce CO2 emissions (air pollution variable) when applied at the port of Benoa.

3.6.3. Scenario 3: Employee Satisfaction Index Improvement by Increasing Compensation to Employees

In the ESG framework issued by the Ministry of Finance Republic of Indonesia [38], improving ESG ratings is a key focus that companies must apply. Enhancing the social aspect, specifically the employee satisfaction index, becomes the third scenario to maintain the sustainability of services at the cruise terminal. The employee satisfaction index is influenced by various factors, such as management policies, compensation for work done, communication in the workplace, and the workload assigned to employees. In the developed baseline model, the employee satisfaction index depends on the revenue generated from passenger arrivals at the terminal. This condition aligns with previous surveys conducted to measure employee satisfaction at the cruise terminal, where the lowest satisfaction rating was given for salary satisfaction, with a total score of 123 out of 150 from all respondents.

Compensation given to employees as bonuses for achieving work targets is one way to improve the employee satisfaction index. The situation at the cruise terminal shows that employees receive overtime compensation when working outside regular hours for cruise ship arrivals and departures. However, there is a limit to overtime hours; once the limit is exceeded, additional hours are not compensated as overtime. In this scenario, a variable is introduced to provide additional compensation based on the number of cruise ship arrivals and the operational revenue generated by the terminal over a year.

3.6.4. Scenario 4: Governance Score Optimization

The ESG framework issued by the Ministry of Finance Republic of Indonesia [38] mandates optimizing all ESG factors for company sustainability, including the governance factor. At the cruise terminal, the governance score reflects governance within ESG. The process for optimizing this score is executed using the developed model. Governance assessment requires consideration of who manages it, what is managed, how it is managed, and its purpose [39]. Port service efficiency, especially for cruise ship arrivals, relies on infrastructure and facilities. Enhancing these, such as upgrading gangways, adding and maintaining conveyors, expanding passenger pick-up areas, and improving immigration services, can significantly reduce embarkation and disembarkation times. This scenario can be simulated by adding a second conveyor unit to expedite luggage handling. To further minimize embarkation and disembarkation times, enhancements in port management, such as streamlining immigration processes and increasing personnel, can help reduce the 60% time spent on immigration.

3.6.5. Scenario 5: Combination of All Scenarios

The development scenario of BMTH, CO_2 emission reduction, improvement of the employee satisfaction index, and optimization of the governance score are some scenarios simulated by expanding the base model from the stock and flow diagram, which was created based on the existing conditions at the cruise terminal. In the previous scenarios, the impact of each scenario on the respective variables was observed when the scenario was executed in each model. In this final scenario, all scenarios are combined to analyze the effects of adding each variable from the respective scenarios when run simultaneously. This combined scenario determines whether running all scenarios together will yield better results than the existing conditions or if each scenario will produce less favorable results in the simulation. The combined stock flow diagram (Scenario 5) is given in Figure 3. Scenarios 1, 2, 3, and 4 can also be represented by this figure. Where, for each scenario, the addition of constants, variables, or factors is relevant to each scenario. For example, for scenario 1, only the BMTH Development constant is added to the "Cruise Berth" stock, and other constants or variables do not apply to this scenario. The same logic will apply to each scenario as well.

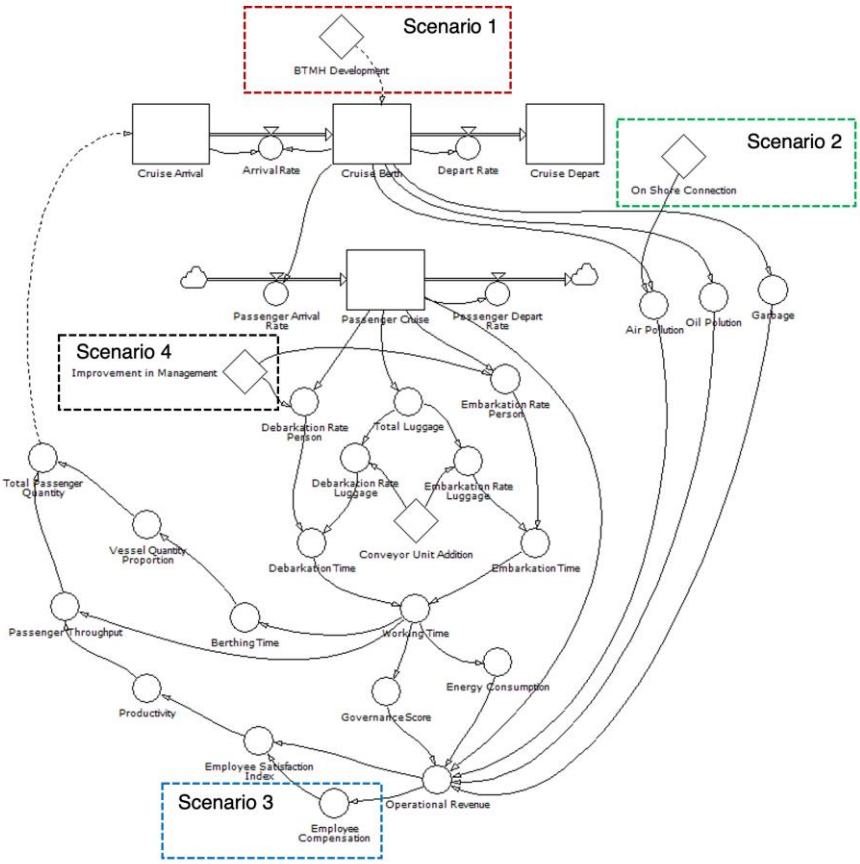

Figure 3.
Stock flow diagram for adopting the scenario in the simulation.

4. Results

4.1. Baseline Case

The stock and flow diagram in Figure 2 is simulated according to the equations in Table 3. The simulation employs a 7-day timestep, calculating each variable for the specified duration at this interval. Based on ship arrival data, the simulation spans 2024 to 2030 to observe changes in variables, particularly those related to ESG standards. The year 2030 aligns with the Sustainable Development Goals (SDGs) to evaluate changes since the program's inception in 2015. Thus, the service simulation at the Port of Benoa Cruise Terminal will continue until 2030, considering changes in service process variables and ESG assessments.

Table 3.
Equations used in the stock flow model.

Auxiliary node	Formula
Passengers' arrival rate	(('Cruise_Berth'/365)*886) / 1<<da>>
Passengers' departure rate	IF('Total Passenger Cruise' < 1000 ; 'Total Passenger Cruise' * 0.1;
Total luggage	('Passenger Cruise')+('Passenger Cruise'*30%)
Debarkation rate person	'Passenger Cruise'/937
Embarkation rate person	'Passenger Cruise'/919
Debarkation rate luggage	'Total Luggage'/1500
Embarkation rate luggage	'Total Luggage'/1460
Debarkation time	MAX('Debarkation Rate Luggage; 'Debarkation Rate Person')
Embarkation time	MAX('Embarkation Rate Luggage; 'Embarkation Rate Person')
Working time	'Debarkation Time'+'Embarkation Time'
Governance score	IF ('Working Time' < 1; 93;
	IF ('Working Time' >= 1 AND 'Working Time' < 2; 91;
	IF ('Working Time' >= 2 AND 'Working Time' < 3; 90;
	IF ('Working Time' >= 3 AND 'Working Time' < 4; 88;
	IF ('Working Time' >= 4 AND 'Working Time' < 5; 86;
	IF ('Working Time' >= 5 AND 'Working Time' < 6; 84;
	IF ('Working Time' >= 6 AND 'Working Time' < 7; 82;
	IF ('Working Time' >= 7 AND 'Working Time' < 8; 80;
Energy consumption	'Working Time'*471.48
Air pollution	'Cruise Berth'*18.,33
Oil pollution	('Cruise Berth'*8.57)/1000
Garbage	('Cruise Berth'*102.68)/1000
Operational revenue	(('Passenger Cruise'*180000)-('Energy Consumption -'*1700)-(('Air Pollution'+'Garbage'+'Oil Pollution -')*1000))*('Governance Score'/100)
Employee satisfaction index	IF('Operational Revenue'<=125000000;86;
	IF('Operational Revenue'>=125000000 AND 'Operational Revenue'<=200000000;90;93.5))
Productivity	IF('Employee Satisfaction Index' < 90 ; 500 ;
	IF('Employee Satisfaction Index' >= 90 AND 'Employee Satisfaction Index' < 91 ; 700 ;
	IF('Employee Satisfaction Index' >= 91 AND 'Employee Satisfaction Index' < 92 ; 800 ;
	IF('Employee Satisfaction Index' >= 92 AND 'Employee Satisfaction Index' < 93 ; 900 ;
	IF('Employee Satisfaction Index' >= 93 AND 'Employee Satisfaction Index' < 94 ; 1000 ;
	IF('Employee Satisfaction Index' >= 94 ; 1200 ; 0))))))
Passenger throughput	'Productivity'*'Working Time'
Berthing time	IF('Working Time'<1; 24 ; IF('Working Time - Copy'>1; 'Working Time'+23.1))
Vessel quantity proportion	(('Berthing Time '/24)*365*0.131)
Total passenger quantity	'Passenger Throughput'*'Vessel Quantity Proportion'
Arrival rate	('Cruise Berth'/365)*'Cruise Arrival' / 1<<yr>>
	IF('Cruise Berth' >= 50; ('Cruise Berth' /365)*10; 0))/1<<yr>>

Tables 4 and 5 present the values of several variables based on the results of the simulation run for the cruise ship service system; the data shown includes annual figures for each variable from 2024 to 2030. In this simulation, all costs are calculated in Indonesian rupiah (IDR).

Table 4.
Simulation result on variables at the cruise terminal (1).

	Variable				
	Cruise berth	**Average passenger per cruise**	**Working time (hours)**	**Operational revenue (IDR)**	**Energy consumption (kW)**
2024	55	837	1.80	125,462,629	850.29
2025	62	1,126	2.43	170,628,314	1,144.72
2026	68	825	1.78	121,783,251	838.01
2027	73	886	1.91	129,453,798	900.36
2028	77	1,402	3.02	208,090,953	1,425.51
2029	80	1,215	2.62	179,244,804	1,235.30
2030	82	748	1.61	107,699,789	760.63

Table 5.
Simulation result on variables at the cruise terminal (2).

	Variable				
	Governance score	**Employee satisfaction index**	**Air pollution (tons)**	**Debarkation time (hour)**	**Embarkation time**
2024	90.43	88.29	10,135	0.89	0.91
2025	90.14	89.43	11,363	1.20	1.23
2026	90.71	88.57	12,463	0.88	0.90
2027	90.14	88.57	13,394	0.95	0.96
2028	88.43	93.71	14,138	1.50	1.53
2029	89.29	91.14	14,694	1.30	1.32
2030	91.00	86.00	15,075	0.80	0.81

In terms of variables related to ESG, namely governance score, employee satisfaction index, and air pollution, changes have occurred alongside the operation of passenger services at the terminal year by year. Environmental factors, specifically air pollution, have increased annually, aligning with the rising number of cruise ships docked at cruise terminals throughout the simulation years. The social factor, represented by the employee satisfaction index, is experiencing fluctuations, as this factor's value is significantly influenced by the income generated from the arrival of cruise ships and the number of passengers at the port. On the governance side, represented by the governance score, a similar condition is observed as with the employee satisfaction index, where the governance score is affected by the working hours variable from the cruise terminal. All variables appear interconnected, influencing one another, per the stock and flow diagram.

Figures 4 and 5 illustrate the model's simulation validation under extreme and normal scenarios. The specific extreme condition tested involved a 20% rise in ship calls (the frequency of cruise ship arrivals at the cruise terminal). The outcomes from both simulations revealed only slight differences in ratios. The model was run for six years, extending to 2030, and the findings validated that the developed model is both suitable and effective for scenario analysis.

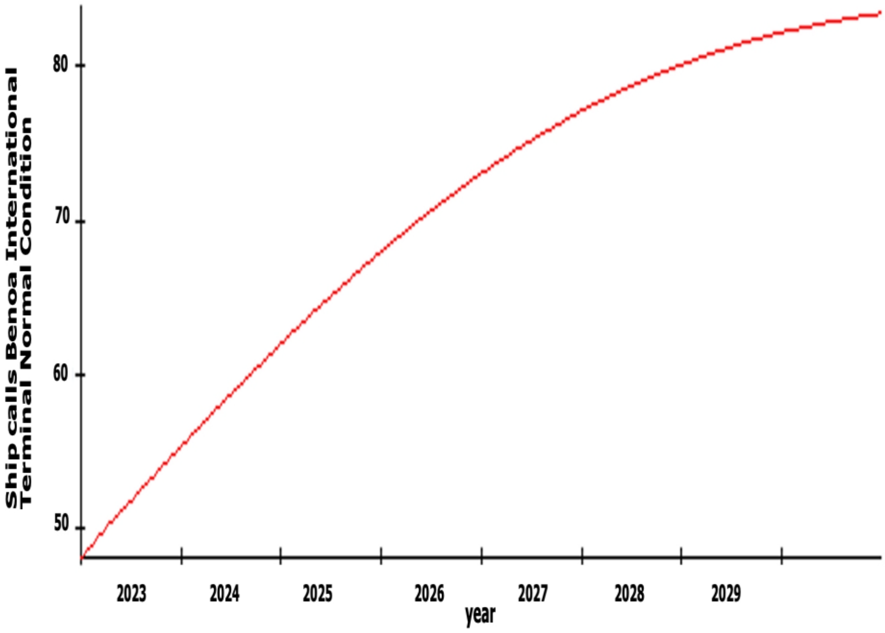

Figure 4.
Simulation output under normal conditions.

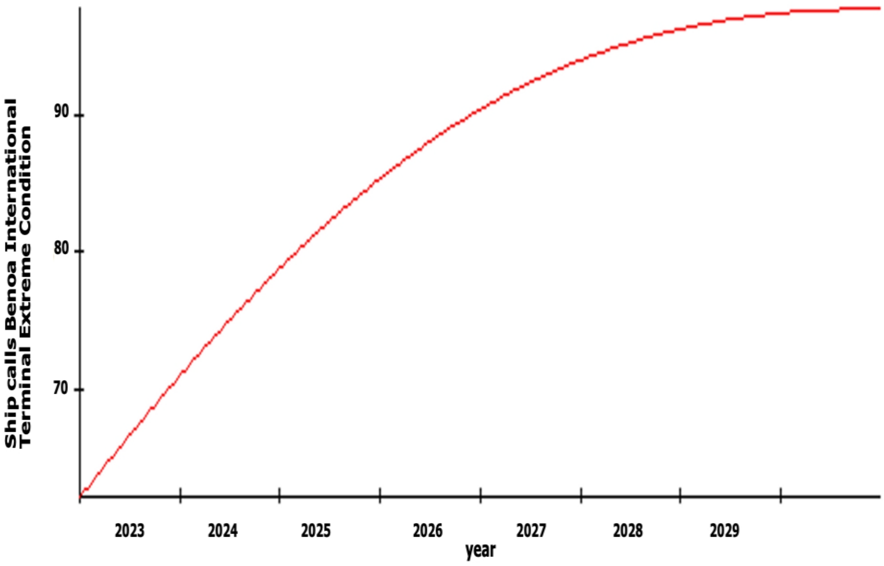

Figure 5.
Simulation output under extreme conditions.

Sensitivity testing involves examining how changes in one variable affect others. In the simulation, all variables changed their values, indicating that each variable effectively influenced the others during the simulation period. This demonstrates that the variables are sufficiently "sensitive" to changes and interact appropriately within the model simulation. The non-state identification model is the phase where the program operates on unlabeled data. The verified model must then undergo validation to confirm the accuracy of the results obtained from the model simulation. The validated data involves the growth in cruise ship arrivals at the terminal. The validation method used is Welch's t-test, which determines whether the average values of the existing conditions and simulation results are significantly different, as given in Table 6. The scenario used for testing is the baseline scenario, representing the terminal service system over five years. Below is the calculation process for validating the passenger service system at the terminal.

Table 1.
Ship calls for existing and simulation results

Annual ship call	Existing	Simulation
Year 1	56	48
Year 2	55	55
Year 3	65	62
Year 4	65	68
Year 5	70	73

The data in the table was then analyzed to find the average value and standard deviation. These values are essential for the validation method, Welch's t-test. Here, the average value and standard deviation are used to calculate the t value and degrees of freedom. In this case, it was found that the t value of the data is 0.188 and the degrees of freedom are 6.8475. The obtained degrees of freedom are then used to determine the critical value, which helps assess whether there is a significant difference between the two validated data sets. The critical value is determined using a t-table at a 95% confidence level, yielding a critical value of 2.365 for the test. Based on the critical value and the calculated t-value, it is observed that the t-value is smaller than the critical value. Therefore, it can be concluded that the hypothesis testing shows no significant difference between the simulated data and the existing data.

4.2. Simulating the Scenarios

Table 7 shows results for Scenario 1, in which the number of visiting ships increases by 1.5 times based on scenario development by BMTH for the year 2027.

Table 7.
Simulation result for scenario 1: BMTH development.

Factor	Before Development				After Development			
	2027	2028	2029	2030	2027	2028	2029	2030
Cruise berth	73	77	80	82	123	133	140	143
Air pollution (ton)	18,769	19,372	19,679	19,772	22,623	24,527	25,727	26,346
Governance score	90.14	88.43	89.29	91.00	88.00	88.00	88.00	88.00
Employee satisfaction index	88.57	93.71	91.14	86.00	95.00	95.00	95.00	95.00

These results show that the increase in cruise ship arrivals significantly impacts the value of ESG factors. The value of air pollution rose drastically, from an initial 19,772 tons in 2030 to 26,346 tons. Meanwhile, the governance score decreased; in 2030, before the development, the simulation results indicated a value of 91.00, which dropped to 88.00 after the development of BMTH. This decline can be attributed to the rising number of cruise ship passengers, which increases the working time variable, directly linked to the governance score. Conversely, the employee satisfaction index improved after the development of BMTH, increasing from 86.00 to 95.00 in 2030. This improvement is likely because the variables that influence it, specifically operational revenue, have risen with the growing number of passenger visits. However, the simulation results for the governance score and employee satisfaction index appear to stagnate. This is likely due to an error in interpreting the indicator value for the governance score. As for the employee satisfaction index, 95 represents an optimal outcome in the simulation. However, it cannot reach 100 due to several other factors influencing it, which are unfortunately limited to those contained within the terminal area in this study.

The simulation results for Scenario 2 are presented in Table 8. Based on these results, it is evident that following the installation of onshore connections at the cruise terminal, CO_2 emissions decreased from 2024 to 2030. In the basic simulation model, the total emissions from cruise ship arrivals were 91,262 tons. After adding onshore connections, emissions reduced to 45,629 tons. This scenario reflects a total emission reduction of 49.99%, which meets the criteria set by Presidential Regulation [40] requiring a 29% reduction in emission values. To ensure the effectiveness of onshore connections, port management must design and implement a policy mandating that cruise ships berthed at the cruise terminal utilize these facilities. This policy must be tailored to the cruise ship arrival data at the port, ensuring that the specifications of the onshore connections align with the electrical requirements of the cruise ships, specifically regarding voltage, current, and frequency.

Table 8.
Simulation result for scenario 2: reducing CO_2 emissions by adding onshore connections.

Factor	Year						
	2024	2025	2026	2027	2028	2029	2030
Cruise berth	55	62	68	73	77	80	82
Air pollution (ton)	5.067	5.681	6.231	6.697	7.069	7.347	7.537
Governance score	90.43	90.14	90.71	90.14	88.43	89.29	91.00
Employee satisfaction index	88.29	89.43	88.57	88.57	93.71	91.14	86.00

The simulation results for the third scenario, which involves providing compensation to employees to enhance the employee satisfaction index, can be found in Table 9.

Table 9.
Simulation result for scenario 3: employee satisfaction index improvement by increasing compensation to the employee

Factor	Year						
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Cruise berth	55	62	68	73	77	80	82
Air pollution (ton)	10,134	11,363	12,463	13,394	14,138	14,694	15,075
Governance score	90.43	90.14	90.71	90.14	88.43	89.29	91.00
Employee satisfaction index	88.61	89.87	89.21	89.21	95.44	92.33	86.10

It is evident that the employee satisfaction index has increased. In the basic model of terminal services, the average value of the employee satisfaction index variable from 2024 to 2030 is 89.38. In contrast, the average value of the employee satisfaction index in this scenario is 90.11. This increase indicates that, in the simulation, the compensation provided to employees impacts the employee satisfaction index, albeit on a modest scale. This compensation variable corresponds to the revenue generated by the terminal during cruise ship services, which is proportional to the number of passengers arriving at the cruise terminal of Benoa. A linear increase in the employee satisfaction index will enhance employee motivation and performance in delivering services that can influence the satisfaction of cruise ship passengers. The models and scenarios created only consider the employee satisfaction factor as a social component in the ESG assessment. But still, other social factors, such as customer satisfaction, will also impact employee satisfaction at the cruise ship reception terminal.

Table 10 presents the results of Scenario 4, illustrating the impact of increasing facilities by adding conveyor units and enhancing management through the addition of immigration services. It also determines passenger embarkation and disembarkation routes on the governance score index.

Table 2.
Simulation result for scenario 4: governance score optimization.

Factor	Year						
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Air pollution (ton)	9,852	10,778	11,558	12,264	12,797	13,192	13,460
Governance score	91.86	90.43	90.71	90.71	90.14	90.43	91.00
Employee satisfaction index	88.29	89.43	87.14	88.57	93.71	91.14	86.00
Energy consumption (kW)	689.14	905.15	649.41	687.08	1,075.4	924.23	565.93

In the baseline model, the average value of the governance score variable from 2024 to 2030 is 90.02. Given the scenario of improvement, the average value increases to 90.75. This increase is insignificant, considering that many other factors influence this variable. The main factors that can affect governance values include tourism management around the port and passenger health and safety, which are other elements impacting governance in the performance of cruise ship ports. In this scenario, only optimization is carried out on the governance score variable, while other variables, such as energy consumption, have decreased compared to the previous basic model. The average energy consumed each year during the simulation in the basic model is 1,022.12 kW. In this scenario, the average energy consumption required by the terminal is 785.19 kW per year during the simulation. This is appropriate because, in optimizing governance, the optimized variable value is the embarkation and disembarkation time, which in this simulation is represented by the working time variable as a combination of the two performance standards. Reducing the terminal's working time will lower the electrical energy consumption.

The simulation results combining all scenarios can be seen in Tables 11 and 12. The information in these two tables indicates that the value of each variable has changed; however, it shows that with the implementation of this scenario, the factors based on the ESG assessment have increased. These factors include air pollution, energy consumption, governance score, and employee satisfaction index. This decline persists despite a simulation predicting an increase of up to 1.5 times from 2027 to 2030 due to the development of BMTH. This suggests that the several factors added to the scenario to help optimize the value of factors in the ESG assessment can function effectively in the simulation system. Although the simulation assumes ideal conditions during cruise ship passenger services and does not consider factors outside the terminal, it can estimate how changes to the management system and facilities at the terminal can enhance the sustainability of services at the terminal.

Table 11.
Simulation result for combined scenarios (1).

	Cruise berth	Average passenger per cruise	Working time (hours)	Operational revenue (IDR)	Energy consumption (kW)
2024	53	813	1.46	128,448,609	689.14
2025	58	1.069	1.92	167,298,016	905.15
2026	63	767	1.38	118,707,258	649.41
2027	120	1.457	2.62	224,172,898	1,234
2028	127	1.551	2.79	238,746,241	1,314
2029	132	1.609	2.89	247,584,863	1,362.39
2030	134	1.636	2.94	251,822,479	1,386

Table 12.
Simulation result for combined scenarios (2)

	Governance score	Employee satisfaction index	Air pollution (tons)	Debarkation time (hour)	Embarkation time
2024	91.86	89.94	4,926	0.72	0.74
2025	90.43	90.31	5,389	0.95	0.97
2026	90.71	89.57	5,794	0.68	0.70
2027	90.14	91.43	11,013	1.30	1.32
2028	90.00	95.00	11,724	1.38	1.41
2029	90.00	95.00	12,154	1.43	1.46
2030	91.00	95.00	12,359	1.46	1.48

4.3. Policy Planning Based on Scenario Simulation Result

The results of the simulations indicate that several scenarios showed positive outcomes for addressing potential issues in passenger services at the cruise terminal. Based on these results, several policy recommendations were made for the management to implement to maintain the sustainability of services at the terminal. The recommendations are tailored to the simulation results, focusing on internal management within the port and the terminal's facilities. The recommended policies to be implemented at the Port of Benoa Cruise Terminal are installation of on-shore connection, this can be adjusted according to the IEEE International Standard [41] which recommend a voltage range of 6.6 – 11 kV, maximum power of 16 – 20 MVA, a frequency of 50 or 60 Hz, and four connection cables leading to the ship, with the system management located at the port. On-shore connection can reduce total emissions by 47% from the overall emissions of cruise ships between 2024 and 2030, especially with the addition of the BMTH scenario, which increases ship visits to the port of Benoa.

The other policies are financial employee compensation based on performance and passenger arrivals [42]. The Indonesia Port Company III in East Java Province, Indonesia, demonstrated that providing compensation can improve performance by up to 22.4%. This compensation policy can be practically implemented by considering employee performance and terminal revenue. In the compensation scenario, financial bonuses can increase the employee satisfaction index by 2.93 points. The last recommended policies are maintenance and addition of conveyor units, immigration services, and embarkation/disembarkation flow optimization. This policy focuses on enhancing the efficiency of passenger embarkation and disembarkation times, thus reducing waiting time at the terminal. This recommendation is based on direct observations made during passenger service at the Port of Benoa. Simulation results show an average increase of 0.59 points in the governance score from 2024 to 2030.

5. Discussion

Based on the ESG assessment, the system dynamics approach is used to model service operations at the Port of Benoa Cruise Terminal. This expands the application of system dynamics within the scope of port operations. The primary assessment, grounded in ESG standards, aims to determine the sustainability of terminal service operations over the coming years. System dynamics facilitates a deeper understanding of the relationships between variables, particularly those related to ESG and the parameter variables specific to the terminal.

5.1. The ESG Assessment in the Cruise Terminal Operation

ESG assessment has been utilized to evaluate the sustainability of port service operations as the standard for assessing sustainability [17]. The core of ESG-based assessment lies in understanding how environmental, social, and governance factors are interconnected with the sustainability of port service operations. Passenger service operations at cruise ship terminals involve numerous factors in their performance. ESG factors are inherently part of what affects the terminal's service performance. However, a focused assessment targeting ESG factors has not been conducted. ESG factors are typically associated with qualitative evaluations and are rarely assessed quantitatively. This is especially true for social and governance factors, where establishing a quantitative basis for their variables can be challenging. Nevertheless, to support a more objective ESG assessment, variables from social and governance aspects have started to be evaluated quantitatively, such as the employee satisfaction index and governance scores of the involved management. With these variables, ESG assessments can be conducted more measurably and objectively.

The selection of variables relevant to passenger service operations and ESG assessment standards is a critical aspect that must be carefully considered. ESG assessments can impact the sustainability and advancement of service operations if the associated variables influence the existing parameter variables [21]. Therefore, in-depth observations and interviews with stakeholders are essential to identify variables directly linked to passenger service operations at cruise ship terminals. Passenger terminals, especially those for cruise ships, have relatively complex service operations compared to cargo terminal operations. Services focus on the efficiency of service time and prioritize passenger comfort throughout the service process.

The ESG assessment is well-suited for application in terminal service operations, as its scope, encompassing environmental, social, and governance factors, provides an evaluation perspective rarely implemented in terminal areas. This assessment offers a broader perspective on passenger service operations at port terminals. However, it is essential to establish boundaries for this evaluation, as including all ESG-related factors as inputs in the system simulation could make the assessment overly extensive. A broader evaluation can be conducted, but it requires the development of sub-systems before forming the main system that encompasses the entire terminal operation process, particularly when involving parties outside the port authority. A more in-depth assessment of variables beyond those listed in Table 1 is necessary to design a more accurate service system, thereby identifying the variables that need improvement with greater clarity and precision.

5.2. System Dynamics Approach to Modelling the Operation System of Cruise Terminal Based on ESG Assessment

ESG assessment requires mapping variables and understanding the correlations between them. The dynamic evolution of service systems presents a challenge, as changes in one variable can directly or indirectly affect others. The system dynamics modelling approach is highly suitable for mapping these relationships. This method allows for simulating system behavior over a specific period and testing various scenarios to observe changes in system behavior [43]. ESG assessment in terminal service operations represents a complex system that necessitates a qualitative approach to identifying the variables within it, followed by a quantitative approach to evaluating the results and determining potential improvements.

System dynamics is an approach that can be modelled qualitatively and quantitatively, where the interconnection of variable information governs system behavior [44]. This makes system dynamics a suitable method for ESG assessment in port service operations, producing relationships between variables within the system, as illustrated in Figure 1. The causal loop diagram is the initial stage in system dynamics modelling and represents the foundational model that depicts the correlation between variables. The development of the system within a system dynamics model can be modified in the causal loop diagram, which acts as the foundation for model development when the system being modelled changes existing conditions. The causal loop diagram, as a qualitative approach in system dynamics, is then developed into a stock flow diagram as a quantitative approach. The stock flow diagram illustrates the quantitative values of variables based on their connections with other variables. The equations for each variable are adjusted according to existing conditions and direct observations with stakeholders, in this case, employees directly involved in the services. The stock flow diagram model, shown in Figure 2, represents the development of the model from the causal loop diagram.

The stock flow diagram illustrates variables as time-function graphs, adjusted according to the specified simulation time frame [45]. In this study, the time frame used is from 2024 to 2030. This time frame is determined based on Presidential Regulation [40] and the UN agenda for achieving sustainable development goals by 2030. The time frame can also be adjusted depending on the needs and dynamics of services at the port terminal. Time-based assessments can assist management in predicting how each variable changes over the years of service operations. These values can be used to test policies that port management will implement in passenger service operations at the terminal.

5.3. Policy Made by the Result of the System Model

The model developed in the stock flow diagram can serve as a tool for testing policies to be implemented at port terminals. Policy testing using the system dynamics model has been applied in various cases [23], which examined the implementation of carbon taxation policies in the port cluster of the Guangdong-Hong Kong-Macao Greater Bay Area and the testing of port congestion alleviation strategies [22]. Using system dynamics for policy testing is a viable strategy to evaluate the impact of a policy on other variables within the system. The effects of the policy can then serve as a basis to determine whether its implementation is appropriate for the port terminal. This decision-making foundation can enhance the effectiveness of implemented policies and serve as a reference for evaluating and formulating other policies at the port terminal.

Policy testing demonstrates that the dynamics within service systems can still be predicted and modeled using the system dynamics approach. Policies that have been implemented can be re-simulated in line with changes in port service operational conditions. Dynamic changes in existing conditions and the model must be evaluated according to the simulation time frame within the model. This evaluation is essential to determine whether the model still accurately represents the current conditions of port operations. The accuracy of the model and its alignment with existing conditions are crucial because policies are formulated based on the simulated model conditions. If the model fails to reflect the existing conditions accurately, the policies developed and implemented may become less effective.

6. Conclusion

This study assesses cruise ship terminal performance using ESG evaluation standards modeled through a system dynamics approach. When serving cruise ship passengers at the terminal, the embarkation and disembarkation times indicate port operational performance. Evaluating port performance from an ESG perspective using a qualitative approach through observation, interviews, and questionnaires revealed that various factors affect terminal service operations. These factors include energy consumption, air pollution, oil pollution, waste management, governance scores, and employee satisfaction indices. Additionally, the elements related to cruise ship passenger services are interconnected and influence one another. The causal loop model illustrates how the number of ship arrivals, passenger numbers, and embarkation/disembarkation service times are interrelated, impacting each other. The simulation scenarios include the impact of infrastructure development on the number of ship and passenger arrivals, the implementation of onshore electric connections which influence energy consumption and CO^2 emissions, enhancements in service through management strategies, and boosting employee satisfaction by offering incentives. Among these improvement scenarios, one notable enhancement in passenger service indicators is the elevation of employee performance. The simulation reveals that post-improvement, the working time was 2.94 hours for 1,636 passengers, compared to 3.02 hours for 1,402 passengers when no infrastructure or performance improvements were applied. Hence, this study recommends several policies, including the installation of onshore connections, financial compensation for employees based on performance and passenger arrivals, the installation of additional conveyor units, improving immigration services, and optimizing embarkation/disembarkation flow to enhance the operational aspect of the terminal. Based on the results obtained through the system dynamics approach, cruise terminal managers will gain a deep understanding of the complex interconnections between factors that can affect terminal performance. Of course, this understanding will enable managers to develop more effective ESG strategies, anticipate the consequences of each decision, and ensure sustainable operations.

However, its implementation requires more in-depth observations, particularly concerning quantitative variables influencing service processes. Comprehensive data collection can further enhance the understanding of system modeling. Inputs from relevant stakeholders involved in port operations can expand insights into the cruise passenger service system within the port. The dynamic nature of passenger service operations can be effectively modeled using a system dynamics approach. However, updating the system model to reflect current conditions, including the addition of new variables or changes to the equations governing variables, is crucial. A continually updated system model can be a solid foundation for developing policies to address future challenges.

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