International Journal of Sustainable Development and Planning
Vol. 19, No. 10, October, 2024, pp. 3901-3910
Journal homepage: http://iieta.org/journals/ijsdp

A Multi-Objective Optimization Business Model for Non-Commercial Port Sustainability

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https://doi.org/10.18280/ijsdp.191018

Received: 3 September 2023
Revised: 29 August 2024
Accepted: 6 September 2024
Available online: 30 October 2024

Keywords:
goal programming, POM QM, port optimization, sustainability

ABSTRACT

Increasing port productivity will affect increasing port income. To be able to achieve this, Resources already in place must be optimized. One option cannot adequately address the complexity of factors affecting port productivity. A method called multiple objectives can assist decision-makers in logically allocating resources by using models for numerous distinct purposes at once. Several objectives must be achieved, including maximizing revenue, minimizing environmental costs, and maximizing the number of workers to design a non-commercial port business optimization model. These goals contain different or even contradictory aspects. For this reason, we need a method that can provide an optimal solution: a meeting point (trade-off) of these goals. The goal programming method can solve problems optimally with more than one (multi) goal objective. The research results show that the product combination resulting from goal programming optimization is more profitable than what the company has done so far. Optimization results fulfil aspects of sustainable port management, namely economic, social, and environmental elements. With this optimization method, port managers can optimize their ports in a balanced way between seeking profits, advancing job growth and minimizing environmental impacts, thus leading to sustainable port management.

1. INTRODUCTION

In the transportation system, the port is a node in the smooth chain of sea and land transportation cargo, which then functions as a transition activity between modes of transport. Maritime logistics effectiveness is crucial for island regions to boost their local economies [1]. Sea transportation services have not only an economic dimension but also a social dimension, where the aim of providing them is not only to serve economic movements but also to help fulfil basic service needs for all Indonesian citizens wherever they are within the territory of the Unitary State of the Republic of Indonesia. Therefore, apart from commercial shipping, which the private sector can carry out, the government is obliged to provide pioneering and subsidized transportation services for remote, outermost, and disadvantaged areas (locational accessibility), as well as helping economically weak groups to obtain sea transportation services at an affordable price (personal accessibility). The Indonesia-centric program has opened access to isolation. It can improve a region's economy and open up isolation by providing accessibility support to the outermost, frontier, disadvantaged, and border regions. The government manages non-commercial ports to serve frontier, outermost, deepest, and border areas not served by land or air transportation. The geographical location and existing natural conditions require sea transportation as a link. The function of the non-commercial ports is solely utilized for pioneer ships serving passenger movements to berth and for the loading and unloading of commodities needed by the local community, particularly in places with insufficient land and air transportation networks. Due to few ship visits and the loading and unloading of cargo, the port's capacity is idle. Government-managed non-commercial ports must be creative to raise money for port operations and facility upkeep. Optimizing the port service industry and governance can lead to innovation and breakthroughs. Port management improvements that include port devolution may enhance port efficiency [2]. Port Authorities have changed from performing simple organizational tasks to gaining greater independence and financial expertise [3]. In the port industry, numerous nations have implemented institutional changes like privatization, corporatization, and the dissolution of port operations functions from the government. These reforms intended to increase port efficiency and improve service quality.

It is necessary to raise the non-commercial port utilities' still-poor performance. Several indicators are used to evaluate port productivity. Port performance indicators are a basis for assessing port development and enhancing port performance and utility [4]. Productivity is not the only metric to evaluate a port's performance to realize a sustainable port. However, it must consider the environmental and societal factors (impact on the surrounding area). Its multifaceted nature in managing maritime transportation logistics necessitates taking into account relationships with organizational, socioeconomic, and ecological variables, as well as a solution-based approach to supply chain and logistics processes [5]. Increasing port productivity will affect increasing port income necessary to optimize existing resources. Resources already in place must be optimized. One decision cannot adequately address the complexity of factors affecting port productivity. One tool that can assist decision-makers in rationalizing Numerous goals involving numerous distinct plans simultaneously are distributed through models [6]. There is still a research gap on non-commercial port business optimization models and strategies in Indonesia. Previous research mainly examined optimization from the operations side and was limited to commercial ports. This study aims to optimize the port according to sustainability aspects, first maximize port productivity (profit) increase production and productivity and increase the added value of port businesses in order to provide effective and efficient port services, maximize regional economic growth (people), increasing port empowerment that can increase economic growth in the surrounding area both directly and indirectly. Provision and absorption of employment both directly and indirectly with port business activities. Minimize environmental impacts (Planet), optimizing the port according to sustainable principles will balance increasing productivity and income by minimizing the negative impacts of port operations on the environment.

2. LITERATURE REVIEW

Port utilities with low performance must be improved. Several indicators are used to evaluate port productivity. Indicators of port performance enhance port functionality, usefulness, and resources for assessing port growth [2]. Basic operations advancing actions, cash reserves, customer loyalty, multimodal integration, and sustainability are all part of a cluster. According to Ha et al. [7], sustainable port performance evaluation must consider social and environmental factors and productivity (Serving neighbourhood life). For coastline and port management, improving sustainable port management to strike a balance between environmental preservation and economic growth thus remains a major challenge [8]. Research in the port industry has established sustainable development more firmly. The relationship between social or environmental impact and economic performance, as well as port competitiveness, has become a growing area of study in this discipline [9].

On the other hand, maintaining a competitive edge and managing stakeholder relations depend on port performance evaluation. It is necessary to evaluate the planned or anticipated performance dimension [10]. However, one or more elements that make up an item, outcome, procedure, or other important part can be numerically quantified using a measurement or efficiency indicator. It must facilitate assessment and contrast with objectives, standards, and previous data [4]. Over time, port development has led to changes in the perceptions of port performance.

Port productivity will influence port revenue growth. One decision resolves the intricacy of the requirements for boosting port efficiency. A variety of goal tools, which use models to accomplish various specific goals simultaneously, can support those who make decisions and simplify the allocation of the resources that are accessible [7]. Hardianto et al. [11] identified economic, social, and environmental indicators for sustainable port performance. The company's critical organizational structure indicators can be observed in the economy. Priority creates value, productivity, financial health, investment level, and service quality. The goal's social dimension is to help the human resource base in the port's surrounding area expand. The variables are knowledge management, training, and fairness. Maintaining the surroundings, optimizing the management of natural resources, observing the consequences of ecological activity, and keeping an eye on the steps taken to decrease their influence through the Port Authorities on the neighborhood communities and port hinterland are all part of the environmental dimension. Clean energy, quality of life, and governance structures are ecological factors.

Although port utilization looks like it has been gaining acceptance, studies on port performance or its connection to the port structure have been scarce for a while. As previously stated, it is clear that extensive literature studies on port sustainability have yet to cover economic and social issues. This work addresses this subject. Hess and Hess [6] look into an innovative efficiency approach for ship cargo management that provides a structural solution for the required cargo handling resources, as well as achieving the lowest total costs at the port and the shortest time needed to complete cargo operations. The proposed model combines the objectives of cost minimization, minimum working hours, and associated resources for managing freight, which is required by ship operators in order to achieve the lowest possible transhipment costs, ship stay costs in port, and service time. Due to the difficulty of the problem, two objective functions are included in an integrated optimization model: the first deals with minimum waiting periods and overall service charges, and the second deals with reducing service periods. The factors employed are the quantity of ship cargo cranes, forklifts, workers involved in securing the cargo, and personnel involved in separating and marking the load. Song et al. [12] researched shipping performance from multiple indicators. Researchers grouped the criteria into 3 (three) groups: operational efficiency, effective service, and environmental impact. The variables are the number of ships, ship speed, and transit time. The method used is a multi-objective genetic algorithm. Kuznetsov et al. [13] researched the development of minor ports in England. Researchers identify whether port activities have adopted sustainability using criteria recognized as the triple bottom line (profit, people, planet). In a business organization, optimization is seen as making business decisions by varying several parameters to maximize profits and reduce losses. Business process design optimization is carried out to create viable business processes by optimizing criteria such as costs, resources, and implementation time. An approach that focuses on structuring business processes, resources, and attributes as a representation of the evaluation of business processes for certain criteria [14]. Cheaitou and Cariou [15] conducted research using a multi-objective optimization approach to creating sustainable sea transportation. Researchers established a multi-objective optimization (MOO) approach that involves maximizing revenue, CO_2 and SOx emission reduction, all of whose objective functions rely on the ship's sailing speed. The article's main conclusion is that the adaptability of demand to transit time is due to the disparity between economic and environmental optimal solutions. Research on multi-objective optimization in ports has not been widely conducted, what is often found is optimization related to scheduling the use of docks and optimizing the capacity of loading and unloading equipment. Cheong et al. [16] use multi-objective evolutionary algorithm (MOEA) for three objectives of handling, waiting time, and degree of departure from a preset priority schedule are minimized in the berth allocation problem. González Laxe et al. [17] identified economic, social, and environmental indicators as sustainable port performance indicators. The financial element reflects basic factors associated with business structure. The emphasis is on value creation, productivity, finances, investment levels, and service quality. The social dimension aims to contribute to the surrounding area and the development of human capital around the port. The variables are fairness, learning, and knowledge-based governance. The environmental aspect is based on the protection of nature, optimization of governance of renewable resources, the impact of operations on the environment, and observing of actions taken by the Port Authority to limit the effects on the surroundings and port society. The variables related to the environment encompass renewable energy use, a healthy environment, and managing environmental systems. Based on a review of previous research, it can be seen that a good port can be seen from its degree of output and budgetary management to the funding of ongoing operations. The foundation of port operations is port governance, and the structure or style of port administration that is chosen has an impact on the port's efficiency and production. The model or form of port administration selected affects the efficiency and effectiveness of the port. Port productivity can be assessed from port performance indicators, which include operational performance, social performance, and environmental performance. To optimize performance, ports must carefully consider which governance model best fits their particular needs and circumstances [17]. Port performance resources can be optimized to achieve various goals. The port seeks to minimize its adverse effects on the environment, boost profitability, and enhance its benefits to the surrounding community. With these conflicting goals, a multi-objective optimization method can be used to achieve the goal. The objective parameters that will be used in the optimization model refer to long-term business goals, such as balancing earnings, port all parties involved, and ecological effects, which, if adapted from the triple bottom line, are people, profit, and the planet. Triple Bottom Line (TBL) optimization is a framework for sustainable business practices focusing on three key dimensions: people, planet, and profit. It's often used to evaluate and optimize business strategies and operations to ensure that they positively impact social, environmental, and economic factors. The triple bottom line's three components are often called the "3Ps.": People: This aspect focuses on sustainability's social and human dimensions. It involves considering the well-being of employees, customers, and the communities in which a business operates. Fair labor practices, diversity and inclusion, worker well-being, and community development are among the people-related goals. Planet: Sustainability of the environment is the focus of the planet dimension. It entails promoting the preservation of ecosystems and reducing the negative consequences that corporate operations have on ecological issues. Reducing carbon emissions, protecting natural resources, cutting waste, and encouraging sustainable sourcing and production are some of the goals in this area. Within the TBL paradigm, profit encompasses monetary gain and overall economic sustainability. It means turning a profit while taking environmental and social costs into account. The aim is to ensure economic growth is sustainable and doesn't harm people or the environment. To maximize the triple bottom line, businesses must create strategies and procedures that balance these three factors. This could entail practicing ethical corporate processes, encouraging social responsibility, lessening the influence on the environment, and figuring out how to turn a profit in the process. This idea pushes companies to think long-term and analyze the wider effects of their decisions. Considered a more comprehensive approach to corporate management, triple-bottom-line optimization recognizes the interdependence of social, environmental, and economic variables. Businesses that successfully apply TBL concepts can benefit all stakeholders in the long run by lowering risk, improving reputation, and creating long-term value.

An expansion of the linear programming model is goal programming. Therefore, first, explain linear programming. Linear programming is a way to solve the problem of allocating limited resources, such as labour, raw materials, machine working hours, and so on, the best possible way to obtain maximum possible results in the form of profit maximization or maximization, which can be in the form of cost minimization. Goal programming is one approach that can be used to address this issue. Analysis goal programming aims to minimize the distance between deviations from the goal, target, or targets set with effort that can be achieved. To achieve a target or goal, one must comply with the requirements to the maximum extent that limits it in the form of resources available, existing technology, and goal constraints [18]. The goal programming method has been widely applied in research previously as a problem-solving solution in solving problems target. McAllister et al. [19] achieve that goal programming is very suitable because goal programming automatically gathers data regarding the relative attainment of existing goals through its deviation variable. Hence, the optimal solution given can be restricted to acceptable responses that combine measurements of desired performance. Chowdary and Slomp [20], in the paper "Production Planning Under Dynamic Product Environment: A Multi-objective Goal Programming Approach", explain that the goal programming method can resolve conflicting aspects between internal elements of production planning, namely consumers, products, and manufacturing processes, that goal programming can be applied in production planning effectively. The goal programming method is also effective when used to determine goals for optimal product combinations and simultaneously achieve the targets the company wants. In order to minimize expenses and the amount of time spent on queue optimization during scheduling at the port, Rahman et al. employ goal programming to schedule and optimize workload of the container production facility [21]. Muren created a port docking model based on a variety of docking objectives which suitable for the queuing problem with multiple service windows and single type service tasks [22].

Goal programming is the best technique when selecting options to reconcile competing objectives under challenging limitations in production planning. The goal programming approach also assists us in achieving optimal responses that are closest to the desired goals.

3. METHOD

Research is a systematically related process. Each stage is a part that determines the next scene. Good research requires an exemplary sequence of research steps. Port optimization research steps include:

Problems identification

The problem identification process is carried out through observation and observing data that exist to find out the problems that occur, where the company's goals contain different, even contradictory, aspects.

Determining research objectives

After knowing exactly what the existing problems are and the related aspects, research objectives can be set. This research aims to maximize workers and revenue and minimize environmental costs by using goal principles programming.

This study used goal programming methods. The general model of goal programming structure is as follows:

Minimize:

$$Z = \sum_{i=1}^{m} (d_i^+ + d_i^-)$$

With goal constraints:

$$C_{11}x_1 + C_{12}x_2 + \cdots + C_{1n}x_n + d_1^- + d_1^+ = b_1$$
$$C_{21}x_1 + C_{22}x_2 + \cdots + C_{2n}x_n + d_2^- + d_2^+ = b_2$$
$$C_{m1}x_1 + C_{m2}x_2 + \cdots + C_{mn}x_n + d_m^- + d_n^+ = b_m$$

Non-negative constraints:

$$xj, d_{1,}^- d_1^+ \geq 0$$
For i=1,2,…,m dan j=1,2,…,n

Definition:

Z denotes the objective function;

$x_1, x_2, \ldots, x_n$ indicates the number of decision variables made to achieve the goal;

$c_1, c_2, \ldots, c_n$ represents the contribution of each decision;

$m_1, m_2, \ldots, m_n$ variable to the objective, often called the objective function coefficient;

$b_1, b_2, \ldots, b_m$, the amount of each existing resource;

d indicates deviation.

Procedures in the goal programming method are as follows:

1) Identifying the decision-making variables

It serves as the depending for a model's decision to find a solution. The more precise the variable determination, the more precise the decision.

2) Determination of the objective function

Namely, the company's objectives to achieve.

3) Establishing the goal function

That is, the deviation variable, both positive and negative, gets increased on the opposing side. By adding variable variation, the desired function's form alters to:

$$f_i(x_i) + d_1^- - d_1^+ = b_i$$

4) Determining top priorities

A target sequence is created in this step. The following factors determine this goal:

a. The decision maker's desire;

b. Constrained current materials.

5) Choosing an appropriate weight

At this point, it is crucial to figure out the importance of the objective compared to other targets.

6) The determination of the achievement function

The key to this case is selecting an uncorrelated variable that is correct to include in the accomplishment of its purpose. A priority-based minimization deviation variable in the achievement function represents each objective.

7) Completion of the Goal Programming model

Goal programming formulation

Establishment of Objective Programming Simulations of the problem to be solved is determining the optimal product combination. Thus, the decision variable is the number of each type of service that will be researched, namely:

X_1 = quantity of general cargo service
X_2 = amount of container service
X_n = number of products n

The objectives of this port optimization modelling will be carried out to determine the amount of cargo that a port must handle to achieve optimal productivity. A port has the following conditions as seen in Table 1.

Table 1. Port condition

No.		Product	Rates	Worker	Wages	Environment Costs
1	X_1	General Cargo	179.450	10	10.000	5384
2	X_2	Container	425.750	8	12.000	66.373

Port conditions assume that handling one container unit requires 5 workers with a wage cost of 12,000 per hour and produces environmental costs of 66.712 Rupiah with a production rate of 223.738 Rupiah.

The constraint function is as follows:

Production capacity	$50 X_1 + 45 X_2 = 4216$
Labor cost	$10 X_1 + 12 X_2 = 1000$
Labor hours	$21 X_1 + 10 X_2 = 720$
Equipment hours	$4 X_1 + 7 X_2 = 216$
Minimum production	$X_1 = 25$ $X_2 = 10$

For the limitations or constraints, it can be explained that the production capacity of a port in handling general cargo is 50 tons per hour and 45 tons per hour for containers with a maximum production of 4216 tons. The maximum labor wage is 100.000 Rupiah per day.

The objectives that want to achieve in sequence are to maximize profit from port operation, maximize employment opportunities and minimize environmental costs. Thus, the formulation of the model to achieve the objectives as follows:

Objective function

Objective 1 (Economic Aspect) Maximize revenue:

$$Z_1 \max Z = 179.450 X_1 + 425.750 X_2$$

Objective 2 (Social Aspect) Maximize labour:

$$Z_2 \max Z = 10 X_1 + 8 X_2$$

Objective 3 (Environment Aspect) Minimize environmental cost:

$$Z_3 \min Z = 5384\ X_1 + 66373\ X_2$$

An optimization model was prepared using the goal programming method from the data obtained in the field. The basis for the mathematical equation, in this case, is the number of goods and the number of containers. X_1 represents the number of goods, and X_2 represents the number of containers. This optimization equation model was created for three types of ports: class I, II, and III. For class I ports, the results are as follows:

The preparation of mathematical equations in the model is outlined in the POM QM program. X_1 is the value of 100 tons of goods, and X_2 is the value of 81 tons of containers. Labour costs are 10 Rupiah for goods and 12 Rupiah for containers, with the expectation of reaching IDR 1000 maximum. Maximum labour hours are 810 hours, with 10 hours per unit of goods and 6 hours per container. The maximum equipment operating hours are 216 hours, with 3 hours per item and 6 per container. General cargo production is 1 ton of goods with a minimum expectation of 50 tons, and container products are 1 ton per container with a minimum expectation of 35 tons. The port model can be seen in Table 2.

Table 2. Port model

	Wt(d)	**Prty(d+)**	**Wt(d-)**	**Prty(d-)**	**X_1**	**X_2**	**RHS**
Capacity	1	1	0	0	100	81	=13860
Labor cost	1	2	0	0	10	12	=1000
Labor hour	1	3	0	0	10	6	=810
Equipment hour	1	1	0	0	3	6	=216
Cargo production	0	0	1	5	1	0	=50
Container production	0	0	1	6	0	1	=35

Based on data processing, it was found that the expected target was 50 goods services and 11 container services. This can be seen from the summary of model results as stated above. The form of these results in a visual graph can be seen in Figure 1.

Based on the results of data processing carried out with the POM QM program, an optimal solution is obtained which is then reanalyzed. The optimal value can be known from the deviation variable. From the previously determined target, namely the limits of the Labor cost, Labor Hour equipment hour. According to the summary of data processing, the port is optimal if it handles the loading and unloading of general cargo of 50 tons per hour and handles 11 boxes of containers per hour. The results of optimal production are substituted into the first objective equation to maximize profit.

$$\max Z = 179.450\ X_1 + 425.750\ X_2$$
$$Z = 179.450\ (50) + 425.750\ (11)$$
$$Z = 13.655.750 \text{ Rupiah per day}$$

So, with optimal conditions, the port will gain a profit of approximately 16 billion. The second objective is to see how much labor is employed, with model:

$$\max Z = 10\ X_1 + 8\ X_2$$
$$Z = 10\ (50) + 8\ (11)$$
$$Z = 588 \text{ worker}$$

in optimal production conditions, the number of workers employed is 588 people. Meanwhile, sustainable optimization from an environmental perspective is minimizing environmental costs with model:

$$\min Z = 5384\ X_1 + 106373\ X_2$$
$$Z = 5384\ (50) + 66373\ (11)$$
$$Z = 999.303 \text{ Rupiah}$$

Item			
Decision variable analysis		Value	
X_1		50	
X_2		11	
Priority analysis		Nonachievement	
Priority 1		0	
Priority 2		0	
Priority 3		0	
Priority 4		0	
Priority 5		0	
Priority 6		24	
Constraint analysis	RHS	d+ (row i)	d- (row i)
Capacity	13860	0	7969
Labour cost	1000	0	368
Labour hour	810	0	244
Equipment hour	216	0	0
Cargo production	50	0	0
Container production	35	0	24

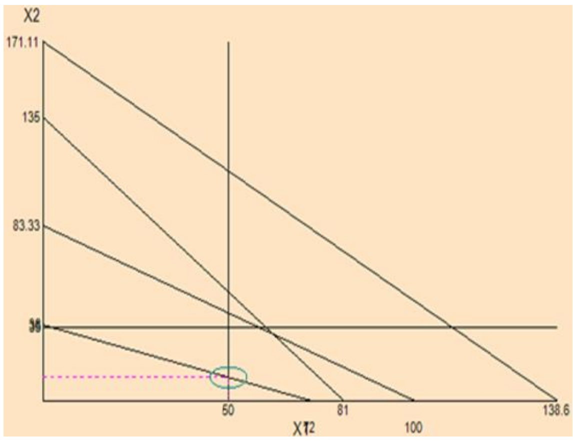

Figure 1. Port model

From the number of cargo that can be handled optimally, the goal of sustainable optimization is obtained, namely gaining profits of 13.655.750 Rupiah per day of the amount of labor recruitment of 588 workers and minimizing environmental costs of the amount of 999.303 Rupiah.

Based on the model findings in Togo, optimal intermodal terminal locations were determined utilizing a LINGO-calculated computational linear algorithm model. This involves considering when simulating the transport network 2023 demand forecasts. These demand forecasts are needed to assess the feasibility of the project. This research in Togo provides an overview of the added value of the transportation sector in Togo. It is the first study to use mathematical linear programming optimization methods to identify optimal intermodal terminal points in the Togo corridor. The results of this study suggest the ideal site for an intermodal terminal is Mango City. The capital of Togo, Lomé, is 550 kilometres north of Mango. The optimization's findings indicate the ideal location for an interconnected terminal to minimize the total cost of transport for container cargo with destinations in three LLCs in Mali, Niger, and Burkina Faso. Following these conclusions, additionally given the rise in trade numbers as a result of this case study illustrates the advantages of multimodal transportation for Togo's transportation sector and makes recommendations in response to the rising demand for cargo transportation between the nations without coasts for policymakers to take action based on the findings [23]. A condition was discovered in a case study in Cyprus that the efficiency of optimizing open ports was not only measured by the number of goods loaded and unloaded but also by the requirements for implementing the key performance index for workers and the digitalization process [24]. Something similar was discovered in Belgian research on vessel flow decision-making. Optimization and efficiency are determined using Big Data input, which is sent using digitalization procedures [25].

However, in other findings carried out at several major ports in China, it was found that the search for optimization of a port was not merely measured based on digitalization factors or simply applying ecological factors. The decision to state whether it is optimal is still seen in the number of loading and unloading goods carried out [26]. This is the same as the findings of Tan et al. [27] in their study, they tried to measure the efficiency of using cranes in operational optimization. Crane use is calculated based on how much cargo and goods utilize the crane's services. In the findings in Dubai, it was found that port optimization management by looking at the efficiency of the flow of goods container traffic is a critical factor in the efficiency and optimization of the work of a port. The level of management efficiency in Dubai is seen by considering the value of containers that have been used (empty containers) [28]. The decision support system in the application of optimization search has been carried out and applied in finding port supply chain efficiency in the Netherlands. The linear programming optimization model is also used in this case in a hybrid manner. The results found that for port operations in the Netherlands, digitalization will be an essential factor in cutting long supply chains [29].

As a conclusion to the discussion, it can be concluded that the application of goal programming in seeking optimization of port operations can be applied and deepened by adding the application of digitalization factors. Calculations are not just calculating the value of transactions and the number of buyers and goods that occur.

4. CONCLUSIONS

Operation and management of ports including loading and unloading of goods, disposal of ship waste and industrial activities in the port will have a significant impact on the environment. Activities that have the potential to have a negative impact on the ecosystem or environment. Therefore, optimal and sustainable port management is needed. This is because the company will gain profit, the local residents and employees around the port will prosper, and the environmental ecosystem will be well maintained. Optimizing sustainable ports, a holistic approach involves three main dimensions: economic, social, and environmental. First, from a financial perspective, ports need to improve operational efficiency by adopting advanced technology, reducing operating costs, and expanding their logistics services to increase their attractiveness to port users. Green infrastructure and clean energy investments should also be prioritized to reduce long-term costs and increase competitiveness. According to the model economic dimension reflected in objective 1 (one) is for maximizing profit. Second, ports need to keep in touch and work with nearby communities and other stakeholders from a social perspective. This entails having frank and candid conversations, watching out for the welfare of port employees, and offering continuing education and job possibilities. Maximizing worker employment is regarding to social dimension which empowerment of communities around the port. Lastly, regarding the environment, ports must lower their carbon footprint by using eco-friendly technology, like the efficient use of renewable energy sources and trash management. Port operations must incorporate sustainable resource management and the preservation of maritime ecosystems. By adopting an all-encompassing strategy, ports can maximize their efficiency while reducing adverse effects and promoting a more sustainable future. The environment dimension according to objective 3 (three) to minimize environment cost.

Ports are one of the key elements in the logistics infrastructure that supports global trade, transportation, and maritime economic activities. In the context of sustainability, sustainable port optimization is very important to ensure that ports not only increase economic efficiency but also support environmental sustainability and social welfare. The environmental impact of port activities is one of the main reasons for the need for sustainable optimization policies. Countries that successfully optimize their ports sustainably will have a competitive advantage in terms of lower operating costs, reduced environmental impacts, and an increased reputation as an environmentally responsible trading center. Overall, sustainable port optimization policies are a strategic step needed to ensure that economic growth can go hand in hand with environmental sustainability and social welfare. Ports significantly influence the socioeconomic development of the areas they service. If they adopt the following tactics, they can serve as catalysts for constructive change. To understand the requirements, goals, and concerns of the local communities, ports must actively interact with them. Regular discussions, open consultations, and feedback channels can guarantee that the port's operations complement local objectives. To safeguard the surrounding environment and marine ecosystems, ports should implement environmentally sustainable procedures. Cleaner emissions, effective waste management, and habitat preservation are initiatives that improve the local community's quality of life while helping the environment. Port infrastructure expansion can boost regional economic growth by boosting trade and freight handling capabilities. But to prevent disturbance or damage to the environment, these expansions must be carried out with consideration for the neighborhood. Ports can provide training and skill development programs with nearby educational institutions. The workforce gains from this investment in human capital, which also gives the port access to a skilled labor pool. Ensuring local communities have access to work possibilities at the port is crucial. Promote local buying and sourcing. Ports can form alliances with nearby companies to purchase goods and services for the port, promoting regional economic growth. This "buying local" strategy helps small and medium-sized businesses (SMEs). Promoting economic growth is one of the primary objectives of optimizing a port.

To diversify their economy, ports should increase the range of services they provide. By adding logistics, warehousing, and manufacturing capabilities, the port can become more than just a transshipment location; it can become a financial hub. Ports are essential to the facilitation of global trade. By putting in place effective procedures for clearing customs and trade-friendly laws, one may draw in enterprises and boost economic growth and cargo volume. Ports should aggressively encourage businesses to locate near them to attract regional investment. Industrial parks and special economic zones can be established to draw businesses and generate employment. Port infrastructure must be continuously invested in. This entails increasing the number of berths, enhancing connectivity with the rail and road systems, and introducing cutting-edge technology to optimize operations. A knowledgeable and driven staff is a vital part of a site prosperous port. Ports should offer its staff members training courses and chances to advance their skills. As a result, the workforce becomes more capable and devoted to their jobs. It is imperative that port management proactively foster diversity and inclusivity within their workforce to guarantee that opportunities are available to individuals from diverse backgrounds. It is essential to cooperate with nearby educational establishments to create curricula specific to the port's labor requirements. Training in maritime studies, supply chain management, and logistics are examples. Prioritizing worker safety and well-being at work is a priority for port authorities. This entails implementing safety procedures, offering health benefits, and attending to labor unions' concerns. Employers should actively seek out candidates from the neighborhood and encourage skill-building initiatives to build a talent pool for the port.

In conclusion, optimizing a port for social development, economic growth, and workforce development requires a holistic approach that prioritizes community engagement, sustainable practices, infrastructure development, and investment promotion. By fostering an environment that supports local economic growth and provides employment and educational opportunities, ports can serve as engines of regional development and contribute significantly to the well-being of the communities they are embedded in. This comprehensive strategy ensures that the positive impacts of port operations are felt across various facets of society, from the local economy to the workforce.

They were minimizing impacts on the environment around the port. Developing more efficient logistics plans and optimizing transportation routes can reduce air pollution and fuel consumption, reducing environmental impact. Regarding infrastructure, ports can consider using environmentally friendly building designs, using recyclable materials, and prioritizing the preservation of the surrounding natural habitat. Collaboration with environmental agencies and other stakeholders is also essential to ensure that sustainable practices become integral to port operations. With these measures, ports can reduce the environmental costs of their operations while supporting nature conservation and ecological sustainability. Optimizing a port's operations to minimize environmental costs is essential in an era marked by growing ecological awareness and the need for sustainable practices. Ports play a pivotal role in global trade and commerce. Still, their operations can also have substantial environmental impacts, from air and water pollution to greenhouse gas emissions and disruption of local ecosystems. Therefore, finding ways to minimize these ecological costs is not just responsible but also critical to long-term economic viability. A multifaceted approach is required, which includes technological innovation, efficient waste management, sustainable logistics, and community engagement. In the following elaboration, we will go into greater detail about these tactics, highlighting their importance in lowering the environmental costs associated with port operations. Using green technologies is one of the most effective ways to reduce environmental costs. To cut carbon emissions, ports can switch to sustainable energy sources like solar and wind power. Furthermore, long-term cost savings can be achieved by investing in cutting-edge energy-efficient technologies such as automated systems and sophisticated sensors that control energy consumption. Carbon emissions and other air pollutants can be decreased using advanced technology, such as electric trucks and electrified freight handling equipment.

Reducing environmental expenses in port operations requires effective trash management. It includes recycling, disposing of garbage properly, and carefully handling dangerous products. The most recent waste management technologies can greatly reduce trash disposal expenses and their negative environmental effects. The circular economy principle should be applied to reduce waste generation and promote recycling.

Efficient logistics not only minimizes costs but also reduces environmental impacts. Optimization of transport routes can cut fuel consumption and emissions, helping mitigate the carbon footprint of the port [30]. Implementing intelligent supply chain management practices and adopting green transportation solutions, such as electric or hybrid vehicles, are integral components of sustainable logistics, resulting in economic and environmental benefits.

Port infrastructure must be designed with sustainability in mind. Using eco-friendly building materials, energy-efficient designs, and adopting sustainable practices, such as rainwater harvesting and waste-water treatment, can reduce the environmental impact. Implementing green building certifications like Leadership in Energy and Environmental Design (LEED) ensures sustainable construction practices. Ports should also aim to protect and preserve the natural habitats surrounding their facilities, contributing to local biodiversity conservation.

Collaboration with environmental agencies and local communities is vital to minimizing environmental costs. Ports must actively engage with stakeholders to ensure their operations align with community and environmental goals. Regular meetings, transparent reporting, and proactive involvement in local conservation programs demonstrate commitment to environmental responsibility and minimize negative externalities. Port operations are often energy-intensive, so energy conservation is crucial for environmental and economic reasons. Simple steps like turning off equipment when not in use and replacing outdated machinery with more efficient models can lead to significant energy savings and reduced environmental impact. Educating and training port employees on sustainable practices and environmental protection can lead to a more responsible and aware workforce. Workers are more likely to actively participate in reducing environmental expenses if they see the value of environmental conservation.

The environmental impact of port activities may be clearly understood thanks to public reporting and regular environmental monitoring. It assists in setting environmental goals and makes it possible to identify areas that require improvement.

Constantly seeking innovative technologies for sustainability is critical to minimizing environmental costs. These technologies could include autonomous transportation systems, advanced pollution control mechanisms, and state-of-the-art environmental monitoring technologies.

Government incentives, such as tax breaks or subsidies, can encourage ports to adopt sustainable practices. These incentives can help offset the initial investments required for green technologies and techniques.

In conclusion, minimizing the environmental costs of port operations is not just a responsible action but also a strategic one. Green and sustainable practices can lead to significant long-term cost savings, enhance the port's reputation, and attract more environmentally conscious business partners. The multifaceted approach, encompassing technological advancements, efficient waste management, sustainable logistics, community engagement, and more, is essential in achieving the dual objectives of economic viability and environmental responsibility. By reducing their environmental costs, ports can serve as models of sustainability and support international efforts to mitigate global warming and protect our natural environment.

The results of this research indicate that ports require optimization according to the level of resources they have. Port maximizing the efficiency of categorizing and sorting is a strategic approach that improves port competitive advantage through maximizing the use of current assets, infrastructure, and services. Policymakers can use the model that has been prepared to be applied in planning and developing non-commercial ports. Optimizing a non-commercial port toward sustainability involves a multifaceted and comprehensive approach considering society, the environment, and financial aspects. Sustainable port management is essential to ensure that ports can meet their current operational needs while also safeguarding the well-being of surrounding communities and minimizing environmental impacts. This complex task can be addressed through a range of strategies and initiatives.

At the core of sustainability for non-commercial ports is balancing their economic viability with environmental and social responsibilities. To begin with, efficient and competitive operations are vital for the financial sustainability of non-commercial ports. Ports must be well-managed to ensure optimal cargo handling, minimize delays, and reduce operational costs. Implementing contemporary technologies, such as digital logistics solutions and automated freight handling systems, can greatly increase efficiency.

Environmental sustainability is similarly essential because ports greatly affect the ecosystem around them. Non-commercial ports might lessen these consequences by using eco-friendly procedures. Important actions include reducing emissions by electrifying or using cleaner fuels, minimizing pollution through waste management systems, and protecting natural habitats in and around the port region. Ports may support sustainable mobility by incorporating rail and waterway linkages to lessen truck traffic and related emissions.

To guarantee social sustainability, non-commercial ports must also interact with their surrounding communities. This includes dealing with traffic jams, noise pollution, and port workers' welfare. To pinpoint and tackle social issues, it is imperative to involve local stakeholders, such as businesses, citizens, and non-governmental groups. Promoting social responsibility and fostering positive relationships can be achieved through community outreach, job training initiatives, and local business support.

Optimizing non-commercial ports towards sustainability also requires them to follow international rules and guidelines. Ensuring safety and security at the port necessitates adherence to the laws of the International Maritime Organization (IMO), including the International Ship and Port Facility Security (ISPS) Code and the International Convention for the Safety of Life at Sea (SOLAS). Furthermore, it is crucial to follow environmental laws and guidelines, such as the MARPOL agreement of IMO, to minimize pollution and preserve a clean and safe environment.

Moreover, infrastructure investment is a major part of optimizing non-commercial ports for sustainability. Port infrastructure development and maintenance are essential for the effective movement of commodities. Upgrades to quay walls, container yard expansion, and deep water access for larger vessels are a few examples of investments that can be made. Energy-efficient buildings, the use of environmentally friendly materials and technology, and the integration of renewable energy sources into the port's energy supply are all important aspects of sustainable infrastructure development.

Increasing non-commercial ports' environmental friendliness requires using sustainable energy sources. To lessen their carbon impact, ports should consider installing solar panels, wind turbines, and energy-efficient lighting systems. Energy-efficient technology implementation can also save costs and support long-term financial viability.

Non-commercial ports should also use cutting-edge technologies to improve their sustainability initiatives. Real-time monitoring and optimization of port operations through the Internet of Things (IoT) can assist in cutting down on energy consumption, idle time, and traffic within the port. Digitalization can enhance stakeholder collaboration and communication, increasing operational transparency and efficiency [31].

Partnerships and collaboration are essential to optimizing non-commercial ports for sustainability. To ensure that their sustainability goals align with larger regional and national goals, ports should collaborate closely with government agencies, local authorities, and non-profit groups. Through knowledge sharing, policy support, and financing opportunities, this collaboration may propel sustainability projects. The sustainability of the supply chain is yet another important factor for non-commercial ports. To encourage sustainable practices, ports should collaborate with their supply chain partners and stakeholders. This may entail enticing shippers to utilize greener and more effective boats, putting sustainable logistics into reality, and embracing the concepts of green supply chain management.

Preserving biodiversity is a critical priority for environmental sustainability. Ports frequently reside in delicate coastal environments; thus, it is important to reduce their ecological impact. Biodiversity assessments and habitat restoration projects can be undertaken to protect and enhance the surrounding environment.

In summary, optimizing a non-commercial port towards sustainability is a multifaceted endeavour that involves economic efficiency, environmental responsibility, and social engagement. Efficient operations, compliance with international regulations, investment in sustainable infrastructure, and the use of innovative technologies are all essential components. Collaboration with stakeholders and supply chain partners, as well as a commitment to community engagement, are crucial for achieving sustainable port management. For the development of a maritime infrastructure that is both environmentally sustainable and efficient, port categorization and clustering will save efficiency resources thereby minimizing environmental costs [32]. By integrating these elements and continually monitoring and improving their sustainability practices, non-commercial ports can contribute to a more sustainable and responsible global transportation network.

Indonesian policies on emissions reduction at ports

The regulation mandates ministries to plan and establish their rules to implement GHG reduction activities. Overall, the law aims to achieve its NDC target by 2030 the amount of 2,869 million tons of CO_2 equivalent. The Ministry of Transport Decree No. 8 of 2023 (Decree of the Minister of Transportation Number K.M. 8 of 2023, 2023) replaces Decree No. 201 of 2013 and sets forth an action plan in the transport sector. The action plan aims to reach the identified target of the enhanced NDC of reducing 31.89% of GHG emissions by 2030. The decree also outlines programs that focus on energy efficiency and the utilization of renewable energy for the maritime transport sector. Mitigation actions listed under energy efficiency focus on reducing air and marine quality impacts of shipping. For the former, the interventions focus on ships using modern technology and managing their energy while in operations [33]. The remaining category concentrates on using energy sources to operate equipment and fixtures used at ports and ships. Some of the interventions in the decree that are relevant to the study include the use of onshore power supply, electrification of cargo handling equipment, use of energy-efficient port fixtures (i.e., LED and solar-powered lighting and navigation aids), use of low-carbon fuels, and use of low-emission fuels. Subsequent decrees or circulars implement the actions in Decree 8/2023. DGST circular letter SE-DJPL No. 22 Year 2022 (28 September 2022) contains regulations on the provision and use of OPS. As a result, Indonesia now has installed OPS infrastructure in 21 different locations. This research is limited to sustainable port optimization in non-commercial ports, for future research it can be considered to examine sustainable optimization in non-commercial ports. In addition, this research can be developed to analyze steps and strategies for achieving sustainable port optimization efforts.

ACKNOWLEDGMENTS

I want to thank Mr. Marimin, Mr. Luky Adrianto, and Mr. Idqan Fahmi for their advice and instruction regarding improving article writing.

REFERENCES

[1] Amin, C., Mulyati, H., Anggraini, E., Kusumastanto, T. (2021). Impact of maritime logistics on archipelagic economic development in eastern Indonesia. The Asian Journal of Shipping and Logistics, 37(2): 157-164. https://doi.org/10.1016/j.ajsl.2021.01.004

[2] Brooks, M.R. (2004). The governance structure of ports. Review of Network Economics, 3(2): 168-181. https://doi.org/10.2202/1446-9022.1049

[3] Brooks, M.R., Cullinane, K. (2006). Devolution, Port Governance, and Port Performance. Elsevier.

[4] United Nations Conference on Trade and Development. (1976). Review of Maritime Transport 2018. Geneva (C.H.): United Nations Publication. https://unctad.org/publication/review-maritime-transport-2018.

[5] Carbone, V., Martino, M.D. (2003). The changing role of ports in supply-chain management: An empirical analysis. Maritime Policy & Management, 30(4): 305-320. https://doi.org/10.1080/0308883032000145618

[6] Hess, M., Hess, S. (2015). Multi-objective ship's cargo handling model. Transport, 30(1): 55-60. https://doi.org/10.3846/16484142.2013.791999

[7] Ha, M.H., Yang, Z., Notteboom, T., Ng, A.K., Heo, M.W. (2017). Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators. Transportation Research Part E: Logistics and Transportation Review, 103: 1-16. https://doi.org/10.1016/j.tre.2017.04.008

[8] Alamoush, A.S., Ölçer, A.I., Ballini, F. (2022). Ports' role in shipping decarbonisation: A common port incentive scheme for shipping greenhouse gas emissions reduction. Cleaner Logistics and Supply Chain, 3: 100021. https://doi.org/10.1016/j.clscn.2021.100021

[9] Lim, S., Pettit, S., Abouarghoub, W., Beresford, A. (2019). Port sustainability and performance: A systematic literature review. Transportation Research Part D: Transport and Environment, 72: 47-64. https://doi.org/10.1016/j.trd.2019.04.009

[10] World Bank. (2003). World Bank Port Reform Toolkit. Washington, DC (U.S.): World Bank. http://documents.worldbank.org/curated/en/120991468762301637/Port-reform-toolkit.

[11] Hardianto, A., Marimin, Adrianto, L., Fahmi, I. (2023). The trend of parameters for evaluating port performance: A systematic literature review. International Journal of Transport Development and Integration, 7(3): 257-266. https://doi.org/10.18280/ijtdi.070309

[12] Song, D., Li, D., Drake, P. (2015). Multi-objective optimization for planning liner shipping service with uncertain port times. Transportation Research Part E Logistics and Transportation Review, 84: 1-22. https://doi.org/10.1016/j.tre.2015.10.001

[13] Kuznetsov, A., Dinwoodie, J., Gibbs, D., Sansom, M., Knowles, H. (2015). Towards a sustainability management system for smaller ports. Marine Policy, 54: 59-68. https://doi.org/10.1016/j.marpol.2014.12.016

[14] Mahammed, N., Benslimane, S.M. (2016). Toward multi criteria optimization of business processes design. In Lecture Notes in Computer Science. https://doi.org/10.1007/978-3-319-45547-1_8

[15] Cheaitou, A., Cariou, P. (2018). Greening of maritime transportation: A multi-objective optimization approach. Annals of Operations Research, 273(1-2): 501-525. https://doi.org/10.1007/s10479-018-2786-2

[16] Cheong, C.Y., Tan, K.C., Liu, D.K., Lin, C.J. (2010). Multi-objective and prioritized berth allocation in container ports. Annals of Operations Research, 180: 63-103. https://doi.org/10.1007/s10479-008-0493-0

[17] González Laxe, F., Martin Bermúdez, F., Martin Palmero, F. (2022). Good practices in strategic port performance. Transactions on Maritime Science, 11(1): 207-218. https://doi.org/10.7225/toms.v11.n01.015

[18] Hasbi, H., Jaya, A.I., Ratianingsih, R. (2017). Penerapan metode goal programming dalam mengoptimalkan pendistribusian bb di kota poso serta meminimumkan

kendaraan yang digunakan berbasis kapasitas tangki spbu. Jurnal Ilmiah Matematika Dan Terapan, 14(1): 107-119. https://doi.org/10.22487/2540766x.2017.v14.i1.8359
[19] McAllister, C.D., Simpson, T.W., Yukish, M. (2000). Goal programming applications in multidisciplinary design optimization. In 8th Symposium on Multidisciplinary Analysis and Optimization 2000, Long Beach, CA, United States, pp. 1-8. https://doi.org/10.2514/6.2000-4717
[20] Chowdary, B.V., Slomp, J. (2002). Production planning under dynamic product environment: A multi-objective goal programming approach. The Annual Research Report.
[21] Rahman, A.T., Sarno, R., Effendi, Y.A. (2018). Goal programming to optimize time and cost for each activity in port container handling. In 2018 International Conference on Information and Communications Technology (ICOIACT), Yogyakarta, Indonesia, pp. 866-871. https://doi.org/10.1109/ICOIACT.2018.8350808
[22] Meng, W., Li, G., Hua, L. (2022). A goal-programming based optimal port docking scheme under COVID-19. Ocean & Coastal Management, 225: 106222. https://doi.org/10.1016/j.ocecoaman.2022.106222
[23] Kalgora, B., Goli, S.Y., Damigou, B., Abdoulkarim, H.T., Amponsem, K.K. (2019). Measuring West-Africa ports efficiency using data envelopment analysis. Journal of Transportation Technologies, 9(3): 287-308. https://doi.org/10.4236/jtts.2019.93018
[24] Michaelides, M., Herodotou, H., Lind, M., Watson, R. (2019). Port-2-Port communication enhancing short sea shipping performance: The case study of Cyprus and the Eastern Mediterranean. Sustainability, 11(7): 1912. https://doi.org/10.3390/su11071912
[25] Li, Y., Zhang, X.H., Lin, K.Y., Huang, Q.B. (2019). The analysis of a simulation of a port–city green cooperative development, based on system dynamics: A case study of Shanghai port, China. Sustainability, 1(21): 5948. https://doi.org/10.3390/su11215948
[26] Natalia, C., Holine, M., Silalahi, A. (2021). A simultaneous container assignment and ship scheduling optimisation model in container shipping. The Asian Journal of Shipping and Logistics, 37(3): 213-219. https://doi.org/10.1016/j.ajsl.2021.05.002
[27] Tan, Z., Zhang, Q., Yuan, Y., Jin, Y. (2022). A decision method on yard cranes transformation and deployment in green ports. Sustainability, 29(1): 323-346. https://doi.org/10.1111/itor.13027
[28] AL-Rikabi, R.B.D. (2019). Optimization Models for Seaport Operations and Empty Container Management. Pretoria: University of Pretoria.
[29] Mar-Ortiz, J., Gracia, M.D., Castillo-García, N. (2018). Challenges in the design of decision support systems for port and maritime supply chains. In Exploring Intelligent Decision Support Systems. Cham: Springer International Publishing.
[30] Yan, X., He, Y., Fan, A. (2023). Carbon footprint prediction considering the evolution of alternative fuels and cargo: A case study of Yangtze river ships. Renewable and Sustainable Energy Reviews, 173: 113068. https://doi.org/10.1016/j.rser.2022.113068
[31] Liu, M., Lai, K., Wong, C.W.Y., Xin, X., Lun, V.Y.H. (2024). Smart ports for sustainable shipping: Concept and practices revisited through the case study of China’s Tianjin port. Maritime Economics & Logistics. https://doi.org/10.1057/s41278-024-00291-3
[32] Hardianto, A., Marimin, A.F., Adrianto, L., Fahmi, I. (2024). The identification of typologies and levels utilization of non-commercial ssssports in Indonesia using the machine learning method. Ingénierie Des Systèmes D Information, 29(4): 1381-1395. https://doi.org/10.18280/isi.290413
[33] Commane, R., Schiferl, L.D. (2022). Climate mitigation policies for cities must consider air quality impacts. Chem, 8(4): 910-923. https://doi.org/10.1016/j.chempr.2022.02.006