Impact Assessment of Green Port Practices on the Triple Bottom Line of Sustainability: The Case of South Asia Pakistan Terminals (SAPT)

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The sustainable operation of ports plays an important and valuable role in achieving overall product reach and logistics. Sustainable port operations ensure production efficiency, profitable business growth and increase customer satisfaction. In developing countries, these practices are neglected and not widely recognized in the literature. The inadequate implementation of these practices in SAPT contributes significantly to greenhouse gas (GHG) emissions, creating problems for the environment and climate change. Therefore, this study examines the implementation of green port practices and answers the question of how these practices contribute to the environmental problems at South Asian Pakistan Terminals (SAPT) and recommends specific practices to transform SAPT into a green terminal. This study is based on a quantitative approach for which data was collected from 172 respondents using a questionnaire on a five-point Likert scale through random sampling. Respondents were selected based on their qualifications, experience and knowledge of green port practices. The model was analyzed using PLS-SEM via Smart PLS 4. PLS-SEM was chosen as the data analysis technique as it can handle complex models in a single trial and provides more generalized results. The results showed that IEM positively and significantly affects GO ($p<0.05$, $\beta=0.356$) and ED ($p<0.05$, $\beta=0.277$). Similarly, ED influences GO ($p<0.05$, $\beta=0.305$), while GO influences ENVIROPER ($p<0.05$, $\beta=0.398$), followed by ECONOPER ($p<0.05$, $\beta=0.303$) and SP ($p<0.05$, $\beta=0.276$). The results imply that Karachi Port Trust (KPT) and Hutchisons Port Holding (HPH) need to address the best practices of green ports in SAPT such as diversification of power generation portfolio, installation of electric Rubber-Tired Gantry (RTG) cranes and electric Internal Transfer Vehicle (ITV) around the port and consideration of Scope III emissions in the value chain of SAPT for sustainable growth and development. The results identify ways to improve the port's sustainability by implementing Green Port Practices (GPPs) that are best suited for SAPT. This study makes a novel contribution to the implementation and achievement of sustainable port performance in the context of developing countries. In the future, other practices such as green purchasing, investment recovery and supplier audits can be operationalized to expand the study.

KEYWORDS

~ Green port practices
~ Green terminal
~ Sustainability
~ Triple Bottom Line
~ Green operations
~ South Asia Pacific Terminal (SAPT)

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1. INTRODUCTION

The transportation and movement of goods has a significant impact on global supply chains, regional production and consumer markets (Aiello et al., 2020). As freight volumes increase, it is claimed that more than 80% of freight transportation will be handled via the maritime network, which in turn requires faster and more efficient seaports (Nguyen et al., 2022). Due to glocalization and modernization, the demand for maritime transport, logistics services, sustainable development and the concept of sustainability itself has gained importance in academia, business, communities and industry (Jović et al., n.d.). In addition, the trend towards environmentally friendly practices in ports has increased in recent years, requiring changes in corporate governance (Castellano et al., 2020). Furthermore, due to the global energy crises and environmental degradation, the idea of green port development has emerged (Hua et al., 2020). This puts pressure on the maritime sector to introduce strict environmental protection regulations.

As the International Association of Ports and Harbors (IAPH, 2010) states, increasing greenhouse gas emissions are one of the main causes of global climate change. Today, ports around the world serve as hubs for transportation, logistics and industrialization, with a variety of manufacturing and shipping activities taking place near the port. The result of these activities are harmful emissions, including the emission of toxic gasses, namely carbon dioxide, nitrogen dioxide and Particulate Matter (PM) which are the largest contributors to greenhouse gas emissions. Literature shows that the industry releases about 1260 million tons of CO_2 emissions annually, accounting for 3.9% of the global carbon footprint, making ports a major source of CO_2 emissions (Yang, 2017). However, in container terminal operations, cargo handling equipment is the main source of exhaust emissions (Eide et al., 2011). Greenhouse gas emissions lead to a poor environmental and social balance. In addition, the costs of poorly embedded operations lead to economic inefficiencies, which may include higher operating costs, delayed shipments, reduced global competitiveness and customer satisfaction. Currently, the importance of SAPT in the Asian region has grown exponentially due to BRI and CPEC. Therefore, it is urgent time to address these inefficient terminal operations from a broader sustainability perspective to close this appealing gap in theory and practice.

The recent increase in maritime activities at sea and in ports raises serious concerns about pollution and waste (Liu et al., 2018; Zhang et al., 2017; Garg et al., 2022), making processes more complex and inefficient. However, as ports are the crucial hub of the global supply chain, they play an important role in linking the global network, regional production and consumer markets. Although ports are the most important mode of transportation, they still lack effective measures to control greenhouse gas emissions, and the consideration of developing ports using environmentally friendly practices is often neglected by relevant authorities (Wang, 2014; Wan et al., 2018). However, environmental awareness in the maritime industry is increasing as laws and standards become more stringent, which in turn puts pressure on the maritime industry to comply with regulations and reduce GHG emissions by reducing waste and pollution levels (Gargm, Kashav & Wang, 2022). The impending regulatory compliance requires ports to adopt environmentally friendly practices, hence the urgent need to pay more attention to environmental protection to ensure port sustainability while facilitating the development of port logistics in the coming decade (Wan et al., 2018) and improving the image of corporate social responsibility (Acciaro, 2015; Lim et al., 2019). For example, with the entry into force of the MARPOL Regulation (Zhang, 2016) and the Kyoto Protocol (Bodansky, 2018), ports are under pressure to meet the social requirements for sustainable functioning. However, ports that do not invest in sustainability are not attractive to stakeholders such as the government, the public, communities and investors.

In addition, GHG emissions and other contaminated gas emissions from such wastes cause high levels of pollution, affecting human health and social life of almost all aquatic species (Guo et al., 2020; Sun et al., 2018; Garg et al., 2022). Therefore, ports must comply with the IMO's 2030 and 2050 emission regulations to strictly follow environmental protection policies and reduce GHG emissions (Chen and Pak, 2017). Although many ports are striving to reduce emission levels and port pollution, it is difficult to achieve this due to the paucity of literature in this area (Garg et al., 2022). Furthermore, Seuring and Muller (2008) and Garg et al. (2022) claim that the existing literature hardly focuses on all three aspects of sustainability (environmental, economic and social), i.e. the Triple Bottom Line (TBL).

The rise in emissions, stakeholder pressure and regulatory requirements are driving organizations to incorporate the concept of sustainability into their decision-making (Halkos & Skouloudis, 2018; Rehman Khan & Yu, 2020). Sustainable port development is a profitable strategy and a perspective for creating a green ecosystem using environmentally friendly practices that help to increase market attractiveness and increase profit margins, leading to better societal and environmental sustainability (Min & Galle, 1997). Although the concept of sustainability is predominantly formulated using the concept of Triple Bottom Line (TBL), Özispa (2021) asserted that for sustainable operations, it is necessary to evaluate the objective of the three basic dimensions of sustainability, i.e. social, environmental and economic dimensions.

However, port development without taking environmental and ecological concerns into account could have a detrimental effect on the inhabitants, fauna and flora in the vicinity of the port. According to Aregall & Bergqvist (2020), the relationship between institutions could open up opportunities for the economic development of ports in the region (Schipper et al., 2017). It could also help to minimize negative aspects such as high-water levels in coastal areas (Hanson et al., 2011), congestion, pollution and noise (Monios et al., 2018; Del Saz-Salazar et al., 2013; Xiao and Lam, 2017). In addition, according to Annex 73/78 of the International Convention for the Prevention of Pollution from Ships (MARPOL) of the International Maritime Organization (IMO), ports should take various measures to achieve their goal of being clean and green.

Despite the existence of sufficient literature on port sustainability, the practical implementation of these research findings is neglected, as few ports have implemented the proposed measures to reduce GHG emissions (Sifakis & Tsoutsos, 2021). In the case of SAPT (South Asia Pakistan Terminals), the port is managed by Hutchison's Port Holding (HPH), one of the largest container port operators with 300 berths and 49 ports in almost 25 countries around the globe. HPH is known for its cutting-edge technology, state-of-the-art terminal operations and environmentally friendly management practices (Lun, 2011, (Rahies et al., 2024a, 2024b)). Therefore, this study investigates the extent to which green management practices are applied at SAPT and the benefits that can be derived from transforming SAPT into a green terminal. Therefore, the following research questions for the SAPT arise from the above problem definition

o *How does the design of the SAPT affect the activities carried out in the port?*

o *How does the management of the SAPT contribute to environmentally friendly operations?*

o *Is the terminal operation at SAPT aligned with the TBL or not?*

2. LITERATURE REVIEW

Lun (2011) investigated the antecedents of green management practices and their relationship to organizational performance. The aim of this study was to formulate a model that defines the GMP factor and illustrates its application using the case of Hutchison Port Holding. The case study approach was used to conduct the study. The results showed that the key antecedents of GMP are collaboration with businesses within the supply chain, environmentally friendly activities and internal management support. It was suggested that managers in the container terminal sector can achieve higher levels of performance by adopting GM practices, which could lead to better terminal throughput, higher productivity and improved cost efficiency.

Garg, Kashav and Wang (2022) investigated the sustainability factors for the establishment of green ports in China. Data was collected from 26 industry experts using the Delphi method, and the proposed factors were evaluated using the Fuzzy Analytic Hierarchy Process (Khan et al. 2024a,b). A total of six factors were identified, of which environmental factors, digitalization, automation and strategy were leading. It was recommended that practitioners need to implement the leading factors in ports to achieve the goal of green port development.

Castellano et al. (2020) evaluated the management systems of Italian ports to measure their environmental and economic efficiency. A multilevel strategy was applied and data was collected from 24 Italian ports. Two factors were assessed, namely the environmental quality resulting from port operations and GHGs emissions, and the environmentally friendly measures taken by the port authorities. The results suggest that it is feasible for ports to develop a comprehensive framework to be both economically and environmentally efficient. It was suggested that managers can achieve their optimal port goals by taking a proactive approach to implementing green port initiatives.

2.1. Theoretical Background

A practice-based view (PBV) is the foundation of the present research study. PBV is an organizational theory framework that focuses on the underlying practices that are publicly known and imitable and can be transferred to other similar businesses. PBV also states that organizations can improve their performance by implementing these practices in simple ways rather than implementing hard-to-adopt practices such as RBV. The framework was adopted in this study to theoretically underpin these practices in an abstract way in terminal operations. This approach helps to investigate how companies adopt and implement green SC management practices and analyzes their relationship with business performance at economic and socio-environmental levels (Carter, Kosmol, and Kaufmann 2017). In addition, the PBV approach can be used to assess changes in performance levels based on the initiatives or practices implemented by the organization. These practices can be emulated and are publicly available (Bromiley and Rau 2014). Furthermore, using the PBV approach helps to demonstrate the change in an organization's performance level based on replicable and transferable practices, where practices can be defined as a "collection of actions that can be undertaken by multiple organizations" (Bromiley and Rau 2014). The dependent variable in PBV is the performance of organizations, while replicable and transferable practices between companies are considered as explanatory variables.

2.2. Hypothesis Development

2.2.1. Internal Environmental Management (IEM) and Eco-design (ED)

IEM is management's commitment to sustainable performance and can only be achieved with the support of top management. In addition, the implementation of innovation also requires the support of the top hierarchy in the case of design (Green et al. 2012, Hebaz et al., 2024). Also, the eco-design of the port and its environmental measures near the port depend on the vision of the port authority, the contribution of the port development company and the input of stakeholders. Moreover, Khan & Yu (2021) claimed that the adoption of environmental sustainability is the most important step for the port authority, and if it has been adopted as a corporate strategy with full support from the top hierarchy, it helps the organizations to implement sustainable ecological design. Therefore, the following hypothesis can be made:

H1: Internal Environmental Management has a positive and significant impact on Eco-design.

2.2.2. Internal Environmental Management (IEM) and Green Operations (GO)

The prerequisite for implementing environmentally friendly practices is internal environmental management, which must be supported by the organization's sustainable philosophy (Martel and Klibi, 2016, Jum'a et al., 2024). This is because strong internal environmental management promotes an organizational culture of environmental responsibility and awareness. Also de Bakker, Fisscher and Brack (2002) and Khan & Yu (2021) emphasized that the adoption of effective environmentally friendly practices depends on top management commitment. Chin, Tat and Sulaiman (2015) and Khalil et al. (2022) also argue that committed implementation by top management is crucial for the adoption of sustainable practices. However, clearly defined rules and guidelines for environmental management provide port personnel with clear recommendations on how to perform their daily tasks in an environmentally friendly manner. Therefore, the following hypothesis can be made:

H2: Internal Environmental Management has a positive and significant impact on environmentally friendly operations.

2.2.3. Eco-Design and Green Operations

The implementation of the environmentally friendly concept already begins in the planning phase of the port. The port is designed from an ecological point of view, i.e. the infrastructure must be planned in such a way that it reduces rework during port operations and promotes a lean approach to carrying out various activities. In the construction phase of the port, environmental issues, dredging of the port and soil disposal need to be considered (Abood, 2007, Sepehri et al., 2024). In addition, energy efficiency, non-optimal resource utilization (due to port design) and inappropriate site selection have a critical impact on port performance and can lead to environmental problems. In addition, Yang (2017) emphasized that the design of a green port must balance the environmental aspects through a balance between process efficiency, carbon footprint and energy savings. In addition, the factors related to ecological design, namely port planning, port infrastructure construction and port operation, create the port ecosystem in line with socio-economic development (Lu, 2024). The following can be derived from this:

H3: Ecological design has a positive and significant impact on Green Operations.

2.2.4. Green Operations and Environmental Performance

Maritime companies are currently overhauling their systems and processes to improve social and economic performance while keeping environmental sustainability in mind (Khan et al., 2019a). Ports have benefited from adopting green port practises in their harbours (Wan et al., 2018, Rubab et al., 2024). For example, the Port of Sydney has adopted green port policies in terms of air quality (Lu and Hu, 2009); the Port of Venice in Italy has adopted a shore-based power supply system, i.e., the Port of La Spezia was able to reduce CO_2 emissions by 30% and NOx emissions by 95 (Wan et al., 2018), and the Port of Lianyungang in China controlled pollutant emissions by using a shore-based power supply (Wan et al., 2018).

However, in the case of SAPT, the port is managed by Hutchison's Port Holdings, and the company is known for developing environmentally friendly internal transfer vehicles (ITVs), namely forklifts, RTGs, front-end loaders, etc. Therefore, the following hypothesis can be made:

H4: Green Operations have a positive and significant impact on environmental performance.

2.2.5. Green Operations and Economic Performance

The study by Kumar, Jain and Kumar (2014) found that there is a positive correlation between a green supply chain (GSC) and a company's profitability. Furthermore, Mitra and Datta (2014) argued that companies seek financial benefits by adopting green practices. Furthermore, it has been claimed that Chinese companies have increased their profitability by adopting green practices in their operations (Khan et al. 2017, Khan et al., 2023a). Furthermore, in the port industry, shipping companies that are more compliant with environmental regulations are likely to be willing to pay more for an environmentally designed port, as previous literature has argued that consumers are willing to pay more money for ecological designs (Lin, Tan and Geng 2013). Furthermore, Lun (2011) recommended that organizations must struggle to achieve the optimal implementation level of green management practices in order to realize the benefits of improved throughput, efficiency, cost-effective operations, and profitability, and thus the economic performance of the port (Wan et al., 2018, Khalil et al., 2022). To achieve economic efficiency, Hutchison International Terminal has converted 70% of its diesel-powered RTGs to electric power to reduce engine maintenance costs and fuel costs by 90% and 65% respectively. Therefore, the following hypothesis can be made:

H5: Green Operations have a positive and significant impact on economic performance.

2.2.6. Green Operations and Social Performance

The conceptualization of sustainability is an important area of concern for society. This means that resources must be used intelligently and wisely to meet society's needs (Khan, et al., 2023). However, the impacts of port operations go beyond this, as they affect not only the people in the immediate vicinity, but also a wider range of communities and societies as a whole. This is mainly due to the effluents emitted from the port hubs such as industrial, recreational and logistics hubs as well as from the ITVs involved in the provision of port services (Sepehri et al., 2024, Siddiqui et al., 2024). In addition, the operation of the port is also important in terms of its impact on society. Garg, Kashav & Wang (2022) claim that special attention needs to be paid to port employees and societies living near the port to consider the societal factors. However, the use of environmentally friendly practices at the terminal leads to a better society near the port and in the communities as a whole and ensures the safety of the natural environment. Furthermore, Yeo et al. (2015) recognized the causal relationship between image and social responsibility. A good image makes the port/terminal more attractive to shippers. Therefore, the following hypothesis can be made:

H6: Eco-design has a positive and significant impact on social performance.

Based on the formulated hypotheses, the conceptual framework presented in Figure 1 shows the impact of IEM on GPPs and furthermore illustrates the impact on sustainable performance, i.e. TBL (economic, environmental and social). The operational definitions of the model constructs are shown in Table 1.

2.2.7. Research Framework

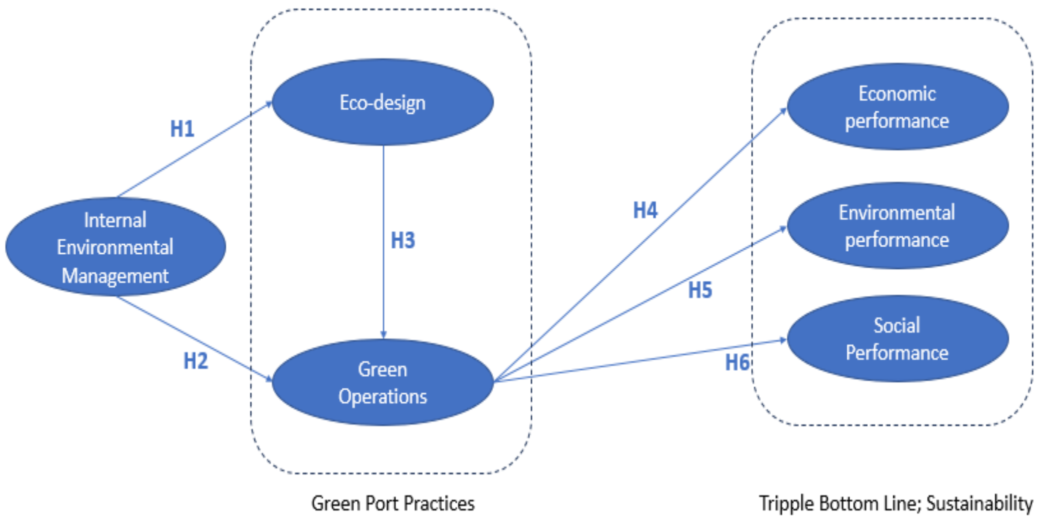

Figure 1 Proposed Research Model

Construct	Definitions
Internal Environmental Management	It refers to the top hierarchical support and commitment towards environmental practices compliance (Afum et al., 2021). It ensures that the port/terminal practices a set of green management initiatives to achieve explicit green targets, such as the deployment of environmental management systems, cross-functional cooperation for the enhancement of the environment, and the establishment of environmental protection indices, and pollution prevention programs.
Eco-Design	It refers to the systematic integration of ecological and sustainable principles in the planning, construction, and operations of the terminal. The design facilitates the reduction in the consumption of energy and material and enables green practices by minimizing the environmental impact of the port's infrastructure (Yang, 2015) by reducing process waste while promoting ecological balance and long-term sustainability.
Green Operations	It can be defined as "the continuous application of an integrated environmental strategy to processes and services to increase efficiency and reduce risks to the environment" (Prasad et al., 2016, p. 412). The Green Operation in this study encompasses low energy usage, lesser emissions, efficient cargo handling, optimal yard planning, and compliance with environmental standards (Kuo & Lin, 2020).
Environmental Performance	It is measured by how well the organization can restrict the adverse impact of its processes on the natural world (Susitha & Nanayakkara, 2023) and promote sustainable development. It also refers to the measurements of the terminal's actions and initiatives in terms of its environmental practices.
Economic Performance	It means the ability of an organization to save financials by adopting green practices (Khan et al., 2021a). The savings may be received by lower material and energy consumption at the terminal via better waste management. Additionally, it refers to the sustainable practices that contribute to the port's economic growth, financial viability, and long-term profitability while considering environmental responsibility into account.
Social Performance	It refers to the evaluation of the organization's activities and initiatives concerning their social impact and contribution toward the well-being of its stakeholders and its workforce (Susitha & Nanayakkara, 2023) involved or affected by the terminal's operation. It can also be defined as the reputation or image of the terminal in the global shipping network due to the adoption of CSR and environmentally responsible activities.

Table 1 Operational Definitions of the Constructs

3. RESEARCH METHODOLOGY AND RESPONDENTS' DEMOGRAPHIC PROFILE

In the present study, a quantitative approach is used to investigate the interrelationships between the variables that form the research model. The study has an explanatory purpose, which means that the concepts and ideas discussed have been explored to some extent in the past, but the gaps in the existing literature needed to be filled. The sample size is calculated using the Daniel Soper calculator (Soper, 2023) and the minimum sample size recommended by the software is 161 (see Appendix-A). However, the data is collected from 172 respondents using a random sample where respondents are selected based on the availability of participants. The target population for this study includes port professionals who are currently working in SAPT or have experience in SAPT operations.

Further on, an online questionnaire based on a Likert scale (five points) was used to obtain responses from the target group. The questionnaire was created using Google forms and sent to respondents via email and LinkedIn. The first part of the questionnaire included questions about respondents' demographic characteristics, including gender, management level, company name and years of experience. The second part included the questions on the model constructs, with responses ranging from "strongly disagree" (1) to "strongly agree" (5).

The data was collected from the terminal professionals who are working or have worked at the South Asian Pakistan Terminal (SAPT) of Karachi Port Trust (KPT). Of the 172 respondents, 143 were male and 29 were female. Most of the respondents were between 36 and 45 years old (36.7%), 13.3% of the respondents were 45 years or older and 46.7% of the respondents were graduates. In terms of management level, most respondents were in middle management (66.7%).

4. DATA ANALYSIS

4.1. Pilot Testing

The information was collected from 172 SAPT participants and initially analysed in a pilot study. The results showed that the Cronbach's alpha value for all variables reached the required threshold of 0.7, indicating the reliability of the instrument used. This led to further analysis using smart PLS 4 to evaluate the measurement and structural models. Smart PLS was used to perform SEM-PLS. SEM-PLS was used for model checking as it can handle the complicated model and perform the full data analysis in a single method. Smart PLS was used as the software of choice for data analysis as it is a user-friendly software that offers the latest insights in the field of data analysis. In addition, it is considered a reliable and accurate software.

4.2. The Measurement/ Outer Model

4.2.1. Factor Loadings

The factor loadings or external loadings shown in Table 2 determine the relationship between the variable and the corresponding indicators (Bagözzi and Yi, 2012). The minimum value of the factor loadings should be at least 0.70. In this study, the values of the external loadings for all items are greater than 0.7, reflecting a correlation between the indicators and the constructs. In addition, ECONOPER1 has an external loading value of 0.626, which is also acceptable (Zohaib & Zaidi, 2022).

	IEM	ED	GO	ENVIROPER	ECONOPER	SP
IEM1	0.768					
IEM2	0.772					
IEM3	0.846					
IEM4	0.753					
ED1		0.814				
ED2		0.866				
ED3		0.836				
ED4		0.782				
GO1			0.828			
GO2			0.855			
GO3			0.818			
ENVIROPER1				0.834		
ENVIROPER2				0.864		
ENVIROPER3				0.816		
ENVIROPER4				0.772		
ECONOPER1					0.626	
ECONOPER2					0.778	
ECONOPER3					0.877	
SP1						0.813
SP2						0.810
SP3						0.774
SP4						0.792

Table 2 Factor Loadings

4.2.2. Internal Consistency Reliability

It measures the relationship between the indicators of similar constructs. Bagozzi and Yi (2012) found that composite reliability (rhoc) is one of the primary measures for assessing internal consistency, the value of which must exceed the minimum threshold of 0.70. Moreover, Cronbach's alpha is used as an alternative measure that has the same threshold as composite reliability. Another coefficient, namely rhoA, is also proposed by some researchers, and its value is between that of Cronbach's alpha and composite reliability (Hair et al., 2021). Table 3 shows the values of all three measures of internal consistency reliability, and it is evident that the model meets the required benchmark for indicator reliability.

Variables	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)
IEM	0.793	0.796	0.866
ED	0.843	0.846	0.895
GO	0.781	0.781	0.873
ENVIROPER	0.845	0.874	0.893
ECONOPER	0.666	0.767	0.808
SP	0.819	0.863	0.875

Table 3. Reliability Analysis*

*Note: IEM=Internal Environmental Management, ED=Eco-Design, GO=Green Operations, ENVIROPER= Environmental Performance, ENVIROPER= Economic Performance, SP=Social Performance.

4.2.3. Convergent and Discriminant Validity

Two types of validities were assessed namely, convergent and discriminant validity. Convergent validity explains the convergence of the construct indicating the indicators' variance. It is measured via the AVE value (Average Variance Extracted), which must be equal to or greater than 0.5 reflecting that 50% of the indicators' variance is explained by the construct (Hair et al., 2021). Table 4 indicates the values of AVE, which enunciates that the model meets the required criterion and exhibits sufficient convergent validity. The AVE values are also represented graphically in Figure 2.

Variables	(AVE)
Internal Environmental Management	0.617
Green Operation	0.695
Eco Design	0.680
Environmental Performance	0.676
Economic Performance	0.589
Social Performance	0.636

Table 4. Convergent Validity evaluated via Average Variance Extracted

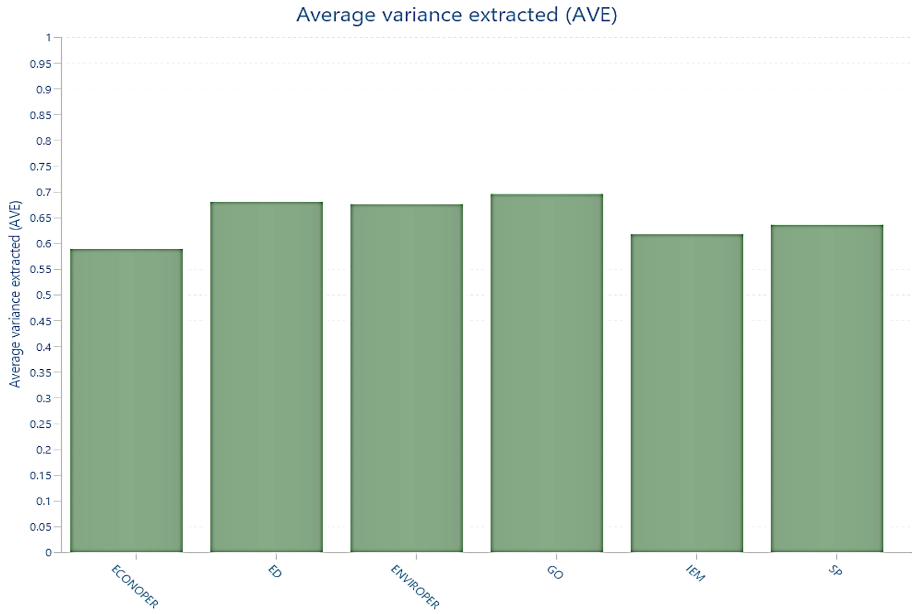

Figure 2. Bar Chart for AVE representing convergent validity.

To assess the discriminant validity of the constructs, which determines the extent to which one construct differs from another in the structural model, the Fornell-Larcker criterion and the heterotrait–monotrait ratio (HTMT) were also measured. Fornell and Larcker's criterion uses the values of the square roots of the variable AVE, which should be higher for similar pairs than for dissimilar pairs (Chin, 1998). The analysis shows that the square roots of the AVEs of IEM, ED, GO, ENVIROPER, ECONOPER and SP are 0.786, 0.825, 0.834, 0.822, 0.767 and 0.797, respectively. In addition, a further criterion, namely HTMT, evaluates discriminant validity, in which the values of the different pairs must be below 0.85 (Henseler et al., 2015). The results for the present model are presented in Table 5 and Table 6, which show that both criteria are successfully met, indicating the presence of discriminant validity.

	IEM	**ED**	**GO**	**ENVIROPER**	**ECONOPER**	**SP**
IEM	0.786					
ED	0.277	0.825				
GO	0.441	0.404	0.834			
ENVIROPER	0.401	0.433	0.398	0.822		
ECONOPER	0.301	0.163	0.303	0.140	0.767	
SP	0.097	0.338	0.276	0.499	0.136	0.797

Table 5. Discriminant Validity - Fornell and Larcker Criteria*

	IEM	**ED**	**GO**	**ENVIROPER**	**ECONOPER**	**SP**
IEM						
ED	0.332					
GO	0.558	0.495				
ENVIROPER	0.344	0.507	0.465			
ECONOPER	0.579	0.204	0.388	0.209		
SP	0.135	0.382	0.317	0.610	0.197	

Table 6. Discriminant Validity - Heterotrait–Monotrait (HTMT) Ratio*

*Note: IEM=Internal Environmental Management, ED=Eco-Design, GO=Green Operations, ENVIROPER= Environmental Performance, ECONOPER= Economic Performance, SP=Social Performance.

4.3. The Structural or Inner Model and Path Analysis

The results of the path analysis represent the relationship between the dependent and independent variables based on a certain level of significance. For the present study, a significance level of 5 % with 5000 bootstrap iterations is assumed. From the results presented in Table 7, it can be seen that the P-values for all variables are below 0.05, which means that all relationships are positively significant. IEM positively and significantly influences GO ($p<0.05$, $\beta=0.356$) and ED ($p<0.05$, $\beta=0.277$). Similarly, ED influences GO ($p<0.05$, $\beta=0.305$), while GO influences ENVIROPER ($p<0.05$, $\beta=0.398$), followed by ECONOPER ($p<0.05$, $\beta=0.303$) and SP ($p<0.05$, $\beta=0.276$).

Path	Coefficient	P values	Results
IEM -> ECD	0.277	0.000	Supported
IEM -> Gr Ops	0.356	0.000	Supported
ECD -> Gr Ops	0.305	0.000	Supported
Gr Ops -> Env Per	0.398	0.000	Supported
Gr Ops -> Eco Per	0.303	0.000	Supported
Gr Ops -> SP	0.276	0.000	Supported

Table 7. Hypotheses Testing

The R-squared or coefficient of determination explains the variance of the dependent variable that can be explained by the independent variables. According to Hair et al. (2021), the values 0.67, 0.33 and 0.19 are considered excellent, moderate and poor respectively. ED is almost 7.7% explained by IEM. However, 28 of GO is explained by IEM and ED. Finally, ENVIROPER, ECONOPER and SP are 15.9%, 9.2% and 7.6% explained by GO, respectively. The values are shown in Figure 3.

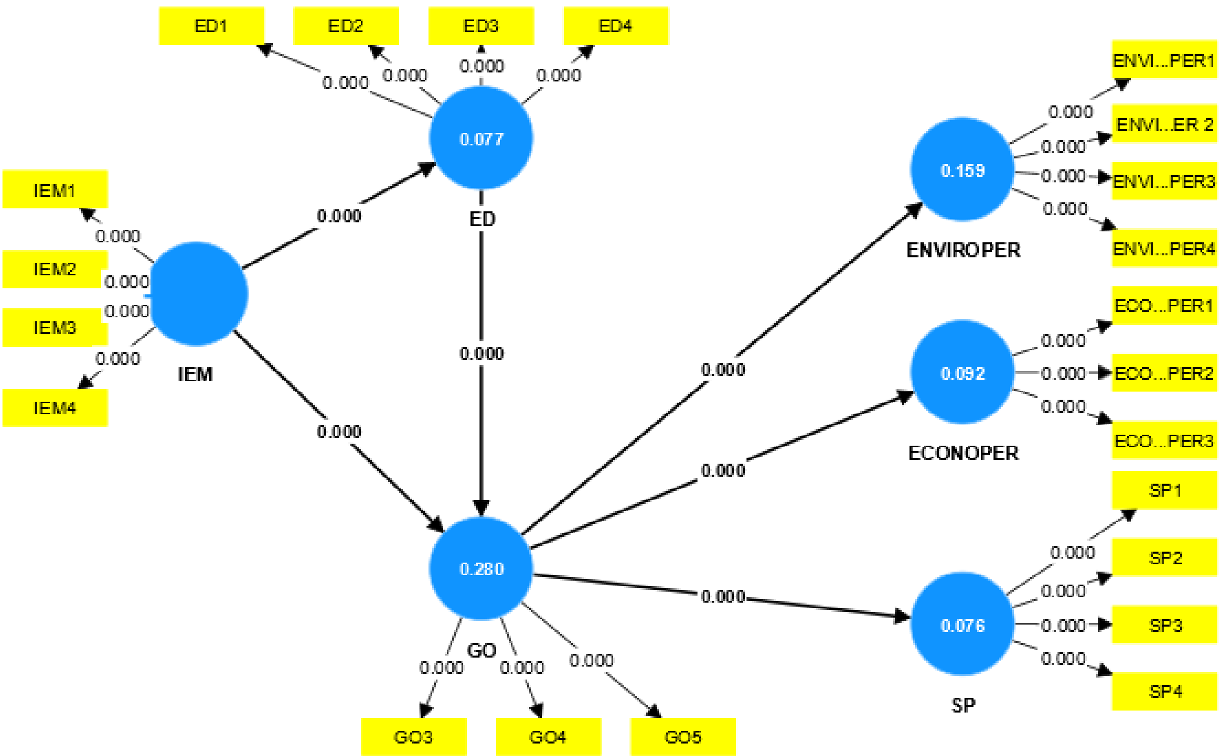

Figure 3 PLS-SEM model after bootstrapping*

*Note: Level of Significance = 0.05, R2 (ED = 0.077, GO = 0.280, ENVIROPER = 0.159, ECONOPER = 0.092 & SP = 0.076).

5. DISCUSSION

H1 states that internal environmental management has a positive effect on the eco-design of products. The results indicate a positive influence of this relationship. The influence of IEM on ED is positive and significant, i.e. SAPT's management always chooses to design the system/processes in a way that reduces effort while maximizing output, focusing on the optimal use of resources. These results are in line with previous research conducted in the field of GSCM implementation in operational activities (M. R. Khan, Khan, et al., 2023b; Rahman et al., 2023). Similarly, Rashid et al. (2025) examined the role of GSCM practices along with JIT and TQM in improving environmental performance in developing countries and found a positive nexus. The ideology of maximizing output with a minimum number of resources is applied from power generation to shipyard and ship design. Our second hypothesis is that the IEM also has a positive impact on Gr operations. The results indicate a positive impact of IEM on green operations. These results are consistent with previous studies also conducted in the context of developing countries (M. R. Khan et al., 2022). Theoretically, these two pieces of evidence support the implementation of GSCM practices in developing countries to enhance the operational performance of companies across all sectors. From a practical perspective, these results motivate firms in developing countries to adopt IEM as a primitive practice to enhance operational performance. Our hypothesis 3 states that product eco-design is related to firm's green operations. The results indicate that the influence of eco-design on green operations is positively significant. In the case of SAPT, the port plays an important role in implementing green operations and reducing resource consumption, resulting in less rework and more cargo throughput. In addition, SAPT has a 700m diameter turning basin, which eliminates the tugboat from the port management model and helps reduce emissions on the seaward side of the port. However, night navigation allows for easy maneuvering in the shipping lanes at night. In addition, internal environmental management is positively and significantly related to green operations. This means that the terminal takes responsibility for its impacts on the environment and the local community. Hutchison’s Port Holding (HPH) in Pakistan has made efforts to ensure socially responsible operations. In this regard, initiatives have been taken by HPH for environment friendly operations and efforts have been made at all Hutchison terminals including SAPT.

Our hypotheses 4, 5 and 6 state that green operations have a positive and significant influence on the economic, environmental and social performance of companies. This study investigated that green operations have a positive and highly significant correlation with the terminal's environmental performance, as the terminal makes every effort to reduce its carbon footprint via GHG emission reduction. These include adding solar energy injection in their energy portfolio, LNG trucks to reduce the combustion footprint of the fleet, Hybrid rubbered tire gantry (RTG) cranes, Regenerative Power absorption System (RPAS), rail networks and improving hinterland accessibility (Khan et al., 2023; Rehman Khan et al., 2022). All these efforts have a strong impact on the environment and lead to less port emissions. The analysis has shown that the environmentally friendly operation of the terminal is positively and significantly correlated with the profitability of the terminal. The terminal is equipped with state-of-the-art infrastructure, including remotely controlled quay cranes, which allows for cost-efficient operations, real-time container tracking and fast service on the eight inbound and six outbound lanes to avoid potential connections near the port. This in turn results in a fast turnaround time and enables cost-efficient processes with lower emissions and resources. In addition, the terminal's own power generation and RPAS reduce fuel consumption and overall costs. In addition, the terminal operating system N-Gen used there makes the processes in the yard and at the quays more efficient, which in turn increases the market attractiveness of the terminal.

Consequently, the SEM analysis revealed that in the case of SAPT, a positive and strong influence of green operations on social performance was identified, i.e. an increase in greener operations would improve the social performance of the terminal, including the social responsibility and image of the terminal in the entire port cluster. To achieve this goal, SAPT does not rely on the national grid for its electricity consumption and generates its electricity in its own power plant, which puts less strain on the national grid. In addition, the terminal's reverse osmosis filtration plant supplies drinking water with minimal environmental impacts. Therefore, the terminal makes every effort to maintain operations while benefiting society and striving to achieve TBL.

6. CONCLUSION

The aim of this study was to investigate the influence of IEM on the eco-design and environmentally friendly operation of SAPT. In addition, the study examined the role of green operations on the economic, environmental and social performance of the company. The results indicate that the introduction of IEM in SAPT has a positive impact on the eco-design and green operation of the terminal and that the green operation of the terminal in turn has a significant influence on the sustainable performance of the port.

6.1. Theoretical and Practical Implications

The study provides practical and theoretical implications for terminal operations in developing countries. From a theoretical perspective, the results demonstrate that the implementation of green practices such as IEM and eco-design supports the operational performance of companies and accelerates resource utilization towards sustainable performance. In terms of practical implications, the findings support that companies in developing countries should accelerate their sustainable performance by implementing initiatives such as IEM, eco-design and green operations. The implementation of these initiatives, especially in developing country ports, contributes significantly to operational efficiency and maximizing the economic, environmental and social welfare of ports. Based on the research findings of the current study, several other recommendations are offered to the port authority i.e. Karachi Port Trust and the port holding company i.e. Hutchisons to make the port more attractive by incorporating wind energy via offshore wind turbines near the port. This will increase reliance on renewable resources, diversify the energy generation portfolio and seek a triple win. First, to improve air and water quality, measures to reduce air emissions from the generation facility and solid emissions are needed to improve the surrounding environment to meet future emissions targets. Additionally, the installation of electric RTGs and electric ITVs near the harbor can reduce air emissions. Secondly, in the case of native vessel monitoring, practices/monitoring devices can be installed along the quay wall to prevent any intentional/unintentional discharge from vessels. Thirdly, best practices for green ports need to be applied in SAPT to achieve sustainable growth and development. To make the SAPT more sustainable, the HIT (Hong Kong International Terminal Footprints) can be followed. Finally, the consideration of scope levels for the value chain of SAPT is highly recommended as green port practices not only emphasize Scope 1 and 2, but also include Scope 3 emissions.

This study, like others, has some limitations that may pave the way for future research. First, this study was conducted from a developing country perspective and focuses only on SAPT. The findings are sufficiently supported to be generalized to port operations in other countries, however, future research could be extended to other port operations in the context of developing countries. Second, only IEM and eco-design are operationalized as green practices in this study. However, other practices such as green purchasing, investment recovery, and supplier audits could be operationalized to expand the study in the future. Finally, the amount of data is limited and the study chose a quantitative approach. However, qualitative and mixed methods studies are welcome in the future to further generalize the results.

DATA AVAILABILITY

The datasets created and/or analyzed during the current research are available upon reasonable request from the corresponding author.

CONFLICT OF INTEREST

The authors state that they do not have any competing interests.

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