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A sustainable shipping management framework in the marine environment: Institutional pressure, eco-design, and cross-functional perspectives

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The shipping industry plays a vital role in the world trading system and in maintaining the stability of global supply chains. However, we cannot ignore the damage it brings to the marine environment. With a focus on protecting the marine environment, the sustainable development of shipping companies has also drawn growing attention. This study examines the sustainable shipping management practice system and develops a comprehensive framework to evaluate the significance of influencing elements and prioritizes those factors. This paper adopts a fuzzy analytic hierarchy process method. It establishes a total of 11 sub-index systems from three aspects: the external policy pressure of shipping companies, the ecological design of shipping services, and the cross-functional green management within shipping companies. We used the fuzzy analytic hierarchy process (FAHP) to analyze data collected from 37 experts in the Chinese shipping industry. The findings show that external policy pressure is the most critical factor influencing sustainable shipping management, followed by eco-design and cross-functional green management. These factors have a big impact and provide management references for shipping company managers and policymakers. They also give the government a company perspective when creating pertinent regulations.

KEYWORDS

sustainable shipping management, fuzzy analytic hierarchy process, institution pressure, eco-design, cross-functional

1 Introduction

With ocean shipping playing an essential role in logistics transportation now, it plays a vital role in maintaining global industrial supply chain stability (Tong, 2022). However, since the COVID-19 pandemic, the world economy has been seriously adversely affected (Pang et al., 2021), and the shipping industry also has faced unprecedented challenges. The impact of COVID-19 on the shipping industry includes, but is not limited to, a decrease in maritime trade volumes (Elmi et al., 2022), terminal closures (Dulebenets, 2022), soaring freight rates (Jin et al., 2022), decreased passenger activity (Chen et al., 2022), and disruptions in global supply chains (Cullinane and Haralambides, 2021).

However, as the aftermath of COVID-19 on the world economy wanes, the demand for shipping services is gradually increasing. The effects of the shipping industry on the environment and society are still a topic of discussion. It's thought that pollutants like greenhouse gases and shipping waste greatly impact the marine ecosystem (Wan et al., 2016; Wu et al., 2020). Researchers regard sustainability as the long-term and ultimate goal of human beings, and the sustainability of the marine environment has also received increasing attention from society (Iannaccone et al., 2020; Tran et al., 2020; Tong, 2022). As a result, policymakers have implemented and tightened various regulations, focusing on the sustainable management of shipping companies.

We cannot overstate the importance of environmental stewardship in contemporary organizations (Jackson et al., 2011; Khatoon et al., 2022). Existing research suggests that environmental practices can improve firm efficiency and provide a competitive advantage (Faleye and Trahan, 2011; Shin et al., 2017; Khatoon et al., 2022). Therefore, companies are becoming increasingly aware of the strategic importance of environmental management practices (Sroufe, 2003; Kleindorfer et al., 2005; Pagell & Gobeli, 2009; Yang et al., 2011). ISO 14001 is the most important environmental management standard, requiring companies to focus on their environmental responsibilities (Nawrocka and Parker, 2009). In addition, environmental law has developed into a specialized legal field, among which UN member states adopted marine protection and sustainable development goals in September 2015 (Ebbesson, 2010; Shamsuzzaman and Islam, 2018).

Regulations about marine environment include different conventions, declarations, and agreements covering the international marine and coastal environment sectors, including the United Nations Convention on the Law of the Sea in 1982 (LOSC), the United Nations Conference on Environment and Development (UNCED), the International Maritime Organization Convention (IMO), and the Convention on Biological Diversity (CBD), among others (Shamsuzzaman and Islam, 2018). As a critical stakeholder, international shipping companies also play an essential role in global sustainable development (Yuen et al., 2018; Wang et al., 2020). Therefore, all these regulations encourage shipping companies to focus on sustainable shipping management (SSM).

Existing studies have researched the impact of the formulation and implementation of environmental management initiatives on corporate performance, but most focus on the financial and business performance of the organization (Yang et al., 2011; Yuen et al., 2019; Tran et al., 2020). In contrast, there is a lack of comprehensive research on the sustainable management of shipping companies. This study refers to the existing research on the company SSM and constructs a framework of influencing factors. In exploring how organizations respond to external policy pressures, this study uses the widely-used institutional theory to investigate organizational adopting and disseminating practices. In contrast to other approaches, such as the resource-based view and dynamic capability theory, we adopted the institutional theory to illustrate how social pressures rather than political and economic factors influence an organization's behaviors and decisions (Tuczek et al., 2018; Yang et al., 2021). This approach is more in line with the purpose of this study, which looks at how shipping companies implement SSM in the face of strict external marine protection regulations. In addition, we introduce the concepts of eco-design and cross-functional green management more comprehensively in the service products and internal management provided by shipping companies, used to consider the influencing factors applicable in SSM. This research fully explores the system of sustainable shipping management from three levels—external environment, service product design, and internal management— to identify the influencing factors, screen their priorities, and determine the sustainable development strategies of shipping companies based on the results.

This study adopts the fuzzy analysis hierarchical process (FAHP) method to solve the above research problems. Researchers use the FAHP for problem-solving, alternative solutions, prioritization, conflict resolution, participatory decision-making, and decision support, and its application has many practical advantages (Haya and Fujii, 2020). This study is crucial because it systematically establishes a structure for evaluating SSM from various aspects, filling the research gap in maritime company development. Researching the practical implications of such a comprehensive evaluation index framework is also important.

The study consists of the following parts. First, section 2 presents a related literature review. Section 3 details the FAHP method and its application in this study. Then, Section 4 presents the findings and discussions. Lastly, Section 5 provides a conclusion and this study's limitations, including the scope of future research.

2 Literature review

This paper provides a thorough analysis and collation of existing research findings to identify sustainability factors in the development of maritime enterprises. There are global-scale discussions on concepts related to sustainable development, such as sustainable shipping management, company environmental performance, and institutional pressure. Although existing research has studied these concepts, problems have also arisen. For example, how sustainable is the shipping enterprise? Also, how does one carry out the sustainable development of a shipping company?

To answer those questions, we refer to the extensive research on sustainability and use the concept of sustainable shipping management (SSM) in existing research to measure it (Li et al., 2017; Su et al., 2020; Aslam et al., 2022; Waqas et al., 2022). We reviewed the existing literature and proposed a more comprehensive framework (institutional pressure, eco-design of shipping services, cross-functional green management) to contribute to the current literature.

2.1 Sustainable shipping management

Many studies indicate that companies should strive for profit, and social and environmental responsibility, i.e., to adopt a management style that seeks sustainable development through social and environmental responsibility (Carter and Rogers, 2008; Balkyte and Tvaronaviciene, 2010; Shin et al., 2017; Dmytriyev et al., 2021). For example, Shin et al. (2017) studied customers' perceptions of the shipping industry's sustainable activity responses. They argued that environmental and social responsibility could improve customer satisfaction and repurchase intentions, leading to a company's improved financial performance and sustainability. In addition, there is also research on shipping companies' sustainable shipping management at the level of resource development and supply chain management—SSM adopts an organization's activities and principles to solve social and environmental issues in its operations to seek sustainable development (Tran et al., 2020).

It is worth noting that internal and external factors influence the company's choice of corporate environmental work objectives. Among these are an understanding of the company's larger-scale operations, environmental ambitions, and financial capacity (Nawrocka and Parker, 2009). Moreover, according to existing research, when considering the conditions for SSM enhancement from the perspective of resources, one needs to consider internal tangible and intangible resources, relational resources, and technical resources (Hart, 1995; Tran et al., 2020). This consideration is also known as sustainable resource development, supply chain collaboration, and sustainable technology development, which can significantly impact the SSM of shipping companies. Also, one needs to consider stakeholder support and participation when using a shipping company's positioning perspective to describe its expected future path, that is, to meet the sustainability needs of stakeholders (Tran et al., 2020).

Researchers have also shown SSM in so many aspects as having a positive impact on company performance (Yang et al., 2011; Shin et al., 2017; Yuen et al., 2019; Tran et al., 2020; Petera et al., 2021). Several factors will impact the achievement of corporate green goals and sustainable development, including government regulation and market competition (Klassen and McLaughlin, 1996; Meng et al., 2019; Ma and Men, 2022), product development that considers the process and environmental performance (Kiurski et al., 2017; Rodrigues et al., 2017; Fung et al., 2021), and internal management that emphasizes the coordination of functional departments (Darnall et al., 2008). However, there has been no systematic review of these factors, so it is impossible to determine the magnitude of the impact of each element on SSM based on existing research. Therefore, one must consider these influencing factors in a complete evaluation system.

2.2 Institutional pressure

As early as the mid-1970s, some scholars put forward institutional theory (IT) when studying organizations. They argued that external factors of "social health" largely shaped organizations' internal structures and procedures, not only external factors relating to the economic goals of cost minimization and profit maximization (Meyer and Rowan, 1977; Dimaggio and Powell, 1983; Guerreiro et al., 2021). A key element of IT includes social behavior, which helps to build a structure's rules, values, and norms, and provides legitimacy to organizations that abide by those rules (Meyer and Rowan, 1977; Guerreiro et al., 2021). Existing research indicates that organizations oriented toward environmental management are better at environmental sustainability than those without environmental management (Nawrocka and Parker, 2009; Ahmed et al., 2021). From a government perspective, regulations related to environmental management indicate that the government is aware of regulatory needs or opportunities that sustainable management systems can address. Regulators at all levels provide possible controls for sustainable development frontrunners, one of the benefits to the organization (Nawrocka and Parker, 2009). In general, under such institutional pressure, organizations gain legitimacy and benefits by actively seeking to meet society's expectations, which has led to an emphasis on company environmental sustainability performance.

Existing research shows that challenging environmental practices such as green product design and adopting green manufacturing processes emphasizing technology and outcomes are susceptible to internal pressures driven by resource and technology scarcity (Flynn et al., 1995; Meng et al., 2019; Ma and Men, 2022). In addition, the management principles or soft environmental management of sustainable policies adopted by a company to improve the environment, such as sustainable information collection, sustainable information disclosure, employee training, and employee participation, are more susceptible to external pressures from the government and market (Klassen and McLaughlin, 1996; Trumpp et al., 2015; Ma and Men, 2022). There are also studies on the impact of government regulations and regulatory measures in the research on supply chain management and regional ecology (Govindan et al., 2014; Mathiyazhagan et al., 2014; Haya and Fujii, 2020), but rarely research on the impact of this on the performance of shipping companies from the perspective of maritime law.

We should note that existing studies have called for the need to formulate appropriate environmental policies, such as mandatory disclosure of environmental information and punishment of environmental violations, to encourage companies to achieve better environmental sustainability (Li et al., 2017). For example, Meng and Zhang (2022) call for governments to make environmental disclosures mandatory for companies by enacting laws and policies. Therefore, in addition to the existing studies on the influencing factors of the environmental performance of shipping enterprises from the aspects of enterprise economy and technology, a more scientific and comprehensive approach to accurately judge the influencing factors of the sustainable management of shipping enterprises is to consider external policy pressures and how management and employees react to it.

According to institutional theory, the impact of regulations and norms on corporate behavior is in three categories: formal laws and regulations, social norms, and informal social knowledge (Mudambi and Navarra, 2002). The enforcement intensity refers to implementing different conventions, declarations, and agreements, established between various countries and world organizations. Numerous studies have shown that institutional pressures from a company's external environment can reshape organizational behavior (Okhmatovskiy and David, 2012; Colwell and Joshi, 2013; Bertassini et al., 2021). Therefore, in this study, we assert that the intensity of

implementing conventions and agreements such as UNCLOS and the IMO Convention will reshape the sustainable management of shipping companies. In addition, Soares et al. (2021) asserted that social norms influence organizational behavior.

In this study, we believe that the initiatives of marine environmental organizations and other societal pressures to regulate environmental protection impact shipping companies' sustainable shipping management behavior. Furthermore, the knowledge (cognitive level) of top management and their employees within an organization can impact its behavior (Contractor et al., 2020). We believe that the environmental knowledge of shipping company management and employees is an essential factor influencing sustainable shipping management. In light of this, we divide the factors that affect the sustainable management of shipping companies into three points: intensity of law enforcement (laws and regulations), normative pressures of the shipping company, and informal social knowledge of the shipping company.

2.3 Eco-design of shipping services

The early stages of a product's development define 80% of its sustainability performance; therefore, company product design must address the sustainability of processes and environmental performance (Rodrigues et al., 2017; Enyoghasi and Badurdeen, 2021; Fung et al., 2021). As such, researchers have proposed the concept of sustainable shipping management to enhance the competitive advantage of shipping companies by lowering costs and providing differentiated services (Lindstad et al., 2016; Lam and Wong, 2018; Yuen et al., 2019; Wang et al., 2021). For example, Wang et al. (2021) proposed that shipping firms create an external sustainable image to enhance competitive advantage while managing sustainably internally. Thus, to provide shipping services, shipping companies must consider sustainability and competitive advantages, which is how to introduce eco-design.

Eco-design is one of a series of initiatives for sustainable development. Its significance is to consider environmental issues during product development and related processes without compromising standards such as function, quality, cost, etc., to reduce the product life cycle's environmental impact (Pigosso et al., 2013; Pigosso et al., 2015; Kiurski et al., 2017; Manzardo et al., 2021; Zeng et al., 2021). In addition, eco-design work is beneficial for companies to gain potential commercial benefits in developing new markets, increasing innovation levels, reducing costs, and compliance (Carroll and Shabana, 2010; Heras-Saizarbitoria et al., 2011; Plouffe et al., 2011).

Existing research has recognized the importance of eco-design and its practice and has mostly focused on product and process-oriented performance research in manufacturing firms (Boks, 2006; Boks and Stevels, 2007; Manzardo et al., 2021; Zeng et al., 2021). But it remains unclear how to integrate eco-design into business processes based on a continuous improvement framework. Therefore, there are also studies on the eco-design management model based on maturity, which explores the best practices of eco-design from three aspects: management practices, operational practices, and methods and tools (Pigosso et al., 2013). In Rodrigues et al. (2017) follow-up study, the researchers combined literature research and experts' opinions to summarize 62 performance indicators of the ecological design process based on implementation, which is currently a more detailed and operable ecological practice performance indicator system. However, all evaluations do not consider the company's higher-level operating systems and strategies (e.g., cost structure, marketing and operating strategies, stakeholders, etc.).

Existing studies have pointed out that internal and external stakeholders play a crucial role in promoting corporate environment-related performance (Klewitz and Hansen, 2014; Kiurski et al., 2017; Nguyen et al., 2021). For example, a study of interviews with 32 printing companies concluded that company owners are important drivers of environmental practices (Kiurski et al., 2017), while production tools and methods that conform to environmental practices are also effective in terms of cost (Borchardt et al., 2011). Research by Nguyen et al. (2021) also confirms that stakeholder engagement and board frequency influence an organization's environmental performance. Moreover, many studies have shown that organizations should fully consider the eco-design of shipping service products at the corporate strategy and operational levels. Therefore, based on previous research, this study refers to the thematic grouping of eco-design practices by Rodrigues et al. (2019) and proposes four indicators: incentives and awareness for eco-design of shipping services, marketing and communication for eco-design of shipping services, portfolio management of shipping services, and value chain management of shipping services.

2.4 Cross-functional green management

Due to the development of enterprise products and services, organizations must be constantly vigilant about market conditions (Srivastava et al., 1998; Payne and Frow, 2005). A competitive market requires the support of different functional areas and promoting internal interdependence between departments (Kang et al., 2021), which involves integration between various functional departments of the company (De Clercq et al., 2011). Cross-functional integration aims to improve coordination between different departments to meet corporate goals (Bergstrom, 1984; Yue et al., 2022). Thus, companies should also consider coordinating their internal functional departments when practicing green management. In terms of organizational capability, companies with high internal integration are better equipped to disseminate, interpret, utilize, and evaluate information and knowledge acquired from external stakeholders (Du et al., 2018; Nguyen et al., 2018).

Studies also show that companies with a high level of internal coordination and communication will be more capable of improving their green management performance if they integrate internally (Johnsen, 2009; Xu et al., 2022). For example, Xu et al. (2022), in a study on supply chain management, verified that cross-functional coordination as a critical mediator effectively influences coercive, normative, and imitative pressures on green innovation. In addition, research shows that cross-functional management positively impacts corporate knowledge sharing, organizational innovation, and corporate operational performance (Love and Roper, 2009; Nguyen et al., 2018; Li et al., 2022).

Some studies have investigated the mechanism of cross-functional management within a company from different dimensions. For example, researchers have combined social capital theory, information theory, and other theories to study cross-functional management and coordination from multiple perspectives involving horizontal and vertical structures, cognition, and relationships, and the impact on knowledge sharing, enterprise innovation, etc. (Nguyen et al., 2018; Li et al., 2022). However, in corporate green development, a company's internal functional departments must formulate coordinated green efforts, such as consistent green strategies and coordinated green processes to achieve green goals (Darnall et al., 2008; Xu et al., 2022). In addition, a company should include the specific implementation measures and subsequent maintenance of cross-functional green management in the scope of management in this area, which is equally important. Accordingly, this study proposes the four indicators based on existing research: establishment of cross-functional environmental policies, responsibilities fulfillment and commitment of cross-functional environmental policies, development and maintenance of the relationship with the other functions, and environmental issues in the delivery process.

3 Methodology

We applied the fuzzy analytic hierarchy process (FAHP), a method combining fuzzy set theory and AHP, to analyze the factor importance in the SSM framework. While AHP is a common technique used by scholars because it works favorably for multi-criteria decision-making, researchers have reported its assessment performance for complex problems to be less satisfactory because the crisp set in AHP can only be unary, which cannot effectively reflect vague or "not well defined" judgments (Munier and Hontoria, 2021). Fuzzy AHP can help address this issue by extending the crisp set to a fuzzy set in which the membership function ranges from [0,1] (i.e., $\mu\tilde{a}(x): R \rightarrow [0,1]$), thus, allowing an infinite membership function. Scholars have commended this approach because of its simplicity and similarity to human reasoning in multi-criteria analysis (e.g., Jakhar and Barua, 2014; Majumdar et al., 2021). We can summarize the main procedure of fuzzy AHP as follows.

The first step is to originate and define the research objective and construct the AHP model accordingly. In doing so, we extensively reviewed the relevant literature and proposed the initial model. After that, three experts (two senior managers from the industry and one professor at a marine engineering university in South Korea) reviewed our proposed model. The experts have at least 15 years of work experience. Based on their feedback, we carefully revised the model. Finally, our model includes three main criteria: institutional pressure with three sub-criteria, eco-design for shipping services with four sub-criteria, and cross-functional green management with four sub-criteria. Figure 1 shows the details of the model and Table 1 sorts out the sub-indicators and their interpretations.

Next, we applied a pair-wise comparison method to compare each criterion with others. Based on responses, we formulated an N × N pair-wise comparison matrix as follows.

$$A = (a_{ij})_{n\times n} = \begin{Bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \ldots & a_{nn} \end{Bmatrix}$$

where a_{ij}=1, when i=j and $a_{ji} = \frac{1}{a_{ij}}$, otherwise. i, j=1,2,…n. However, this matrix is only valid when the consistency ratio (CR) is below 0.1. To measure CR, we used the method Gogus and Boucher (1998) recommended, and the calculation is as follows.

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{max} - n}{n-1}$$

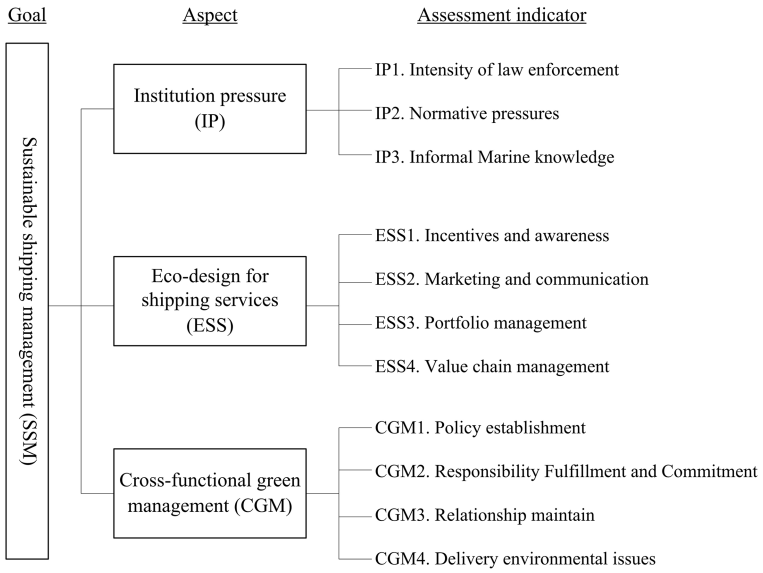

FIGURE 1
The hierarchical structure for SSM.

TABLE 1 The indicators affecting sustainable shipping management (SSM) and definitions from literature.

Aspect	Assessment Indicator	Definition	Source
Institutional pressure (IP)	IP1. Intensity of law enforcement	Implementing maritime conventions, such as the United Nations Convention on the Law of the Sea and the IMO Convention.	Contractor et al., 2020; Mudambi & Navarra, 2002
	IP2. Normative pressures	Marine Environmental Protection Group initiatives and other marine norms pressure shipping companies to protect the environment.	
	IP3. Informal marine knowledge	Marine environmental knowledge of shipping company management and employees.	
Eco-design for shipping services (ESS)	ESS1.Incentives and awareness	Increase consciousness and awareness about the opportunities and benefits of integrating environmental issues in product development.	Pigosso et al., 2013; Rodrigues et al., 2017
	ESS2. Marketing and communication	Communicate the environmental performance and benefits as part of the total value proposition of the product, exploring green marketing opportunities.	
	ESS3. Portfolio management	Strategically consider the product's environmental performance in the shipping company's portfolio management.	
	ES4. Value chain management	Consider the environmental aspects in the identification, qualification and management of suppliers.	
Cross-functional green management (CGM)	CGM1. Policy establishment	Establish green goals, actions and performance measurements across departments within the company.	De Clercq et al., 2011; Pinto et al., 1993; Yue et al., 2022
	CGM2. Responsibility fulfillment and commitment	Emphasize cross-functional decision-making autonomy and the fulfillment of shared responsibility, such as the extent to which functional managers perceive knowledge exchange with peers in other departments and shared goals related to the organization's overall well-being.	
	CGM3. Relationship maintenance	Coordinate cross-functionally among shipping enterprise departments and emphasize effective and collaborative relationships between departments.	
	CGM4. Delivery environmental issues	Companies' commercial interests are linked to the sustainability of shipping services.	

$$\lambda_{max} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}\left(\frac{w_j}{w_i}\right)}{n}$$

Where *RI* is the random index (Table 2), *n* is the matrix size, *w* is the weight vectors, and Λ_{max} is the maximum eigenvalue (Saaty, 1980). For instance, if the matrix size is three (n = 3), we would use RI = 0.52 for the CR calculation.

While there are numerous methods to calculate the fuzzy number (e.g., triangular, trapezoidal, Gaussian), we employed the triangular fuzzy number (TFN) in this study because of its computational simplicity in operating the crisp numbers into a fuzzy set. The following shows the TFN calculation. Table 3 reports the fuzzy comparison measures (Gumus, 2009).

$$\mu(x|M) = \begin{cases} \frac{x-l}{m-l}, & x \in [l, m], \\ \frac{x-u}{m-u}, & x \in [m, u], \\ 0, & otherwise \end{cases}$$

where *l*, *u*, and *m* are lower, modal, and upper values, respectively ($l \le m \le u$).

The basic operation of TFN for constructing a fuzzy comparison matrix is as follows (Majumdar et al., 2021).

Let $\widetilde{N_1} = (l_1, m_1, u_1)$ and $\widetilde{N_2} = (l_2, m_2, u_2)$ represent two TFNs.

$\widetilde{N_1} \oplus \widetilde{N_2} = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$, for addition

$\widetilde{N_1} - \widetilde{N_2} = (l_1 - l_2, m_1 - m_2, u_1 - u_2)$, for subtraction

$\widetilde{N_1} \otimes \widetilde{N_2} = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)$, for multiplication

$\widetilde{N_1}/\widetilde{N_2} = (l_1 \div l_2, m_1 \div m_2, u_1 \div u_2)$, for division

$\widetilde{N_1}^{-1} = (u_1^{-1}, m_1^{-1}, l_1^{-1})$, for inverse

For example, for $\widetilde{N_1} = (1, 1, 1)$ and $\widetilde{N_2} = (1, 2, 3)$, the result for the addition of summing two TFNs is $\widetilde{N_1} \oplus \widetilde{N_2} = (1 + 1, 1 + 2, 1 + 3) = (1, 3, 4)$To determine the criteria weights, we first calculated each criteria's fuzzy geometric mean, then calculated the fuzzy weights. The formula for fuzzy geometric mean calculation is below.

Assume that $\widetilde{D_i}$ is the fuzzy set of *n* responses for criteria *i*, the fuzzy geometric mean of this criteria is $\widetilde{D_i} = (\widetilde{a_{i1}} \otimes \widetilde{a_{i2}} \otimes \ldots \widetilde{a_{in}})^{\frac{1}{n}}$, and the fuzzy weights are $\widetilde{C_i} = \widetilde{D_i} \otimes (\widetilde{D_1} \oplus \widetilde{D_2} \oplus \ldots \widetilde{D_n})^{-1}$.

TABLE 2 Random index.

Size	1	2	3	4	5	6
RI	0	0	0.52	0.89	1.11	1.25

Source, Saaty, 1980.

TABLE 3 Fuzzy comparison measures.

Linguistics Terms	Triangular Fuzzy Numbers
Perfect	(8, 9, 10)
Absolute	(7, 8, 9)
Very good	(6, 7, 8)
Fairly good	(5, 6, 7)
Good	(4, 5, 6)
Preferable	(3, 4, 5)
Not bad	(2, 3, 4)
Weak advantage	(1, 2, 3)
Equal	(1, 1, 1)

Finally, we defuzzied and normalized the calculated weights to show the relative importance of the criterion. Following Hsieh et al. (2004), we applied the center of area method to determine the best nonfuzzy performance (BNP) values, and the calculation is as follows.

$$BNP_i = \frac{[(u_i - l_i) + (m_i - l_i)]}{3} + l_i$$

Based on the BNP values, we can derive the importance ranking of each criterion after normalization. Finally, after calculating the importance weights of each criterion and sub-criterion, we can obtain the global importance scores of the sub-criteria by multiplying the local scores of the sub-criteria with the importance weights of the criteria.

4 Results

We collected the data used in this study through a questionnaire survey with employees of shipping companies and researchers in maritime transportation. The questionnaire included three sections. The first section introduced the purpose of our study and covered anonymity and confidentially. Respondents who clicked "agree" were directed to the next section, which asked about their demographic characteristics, such as sector, work experience, and position. The last section requested the respondents to compare and rate the importance of the constructs of the model. Initially, we sent an invitation with a link to the survey to 100 employees and 100 researchers. A month later, we sent the link again to remind potential participants who had not yet completed the questionnaire and to inform them that they had 15 days to complete the survey. Eventually, we received 46 responses, a response rate of 23%. Because there were nine incomplete answers, our final dataset contained 37 replies.

Table 4 shows the demographics of the 37 respondents. The respondents' positions included 51.35% in director roles and above, 29.73% in manager roles, and the remaining held non-managerial positions. The respondents' work experience ranged from more than ten years (24.32%) to five-to-ten years (56.76%) and less than five years (18.92%). Furthermore, 59.46% of the respondents came from companies with 101–200 employees, while 18.92% and 21.62% were from companies with more than 200 employees and companies with less than 100 employees, respectively.

Following Zhao et al. (2022), we calculated the response consistency ratio and weights based on mean values. The analysis results are in Table 5.

Overall, the results of consistency ratio tests for all criteria were below 0.1 (ranging from 0.019 to 0.071), suggesting consistent matrices. Table 5 reports the local and global weights of the criteria. For the main criteria, we found institutional pressure as the most critical factor (0.549), followed by eco-design for shipping services (0.288) and cross-functional green management (0.163). The findings of this analysis point to the importance of external policy pressure in supporting the adoption of SSM. Thus, companies must simultaneously consider the eco-design of shipping services and internal cross-functional green management.

We then took a closer look at the importance weights of the sub-criteria. First, normative pressure (0.356) was the most important sub-criteria of institutional pressure, followed by intensity of law enforcement (0.343) and informal social knowledge (0.301). Notably,

TABLE 4 Demographics of respondents.

Profile Information	Number of Respondents (n=37)	Percentage (%)
Job position		
Director and above	19	51.35
Manager	11	29.73
Non-manager	7	18.92
Working experience in the company (years)		
>10	9	24.32
5–10	21	56.76
<5	7	18.92
Firm's size (number of employees)		
>200	7	18.92
101–200	22	59.46
<100	8	21.62

these factors also ranked in the top three globally. This finding demonstrates that institutional theory's emphasis on normative pressure, law enforcement, and informal social knowledge is essential for shipping businesses to consider if they wish to maintain a decent, sustainable development. In descending order, the sub-criteria of eco-design for shipping services are portfolio management (0.422), marketing and communication (0.314), incentives and awareness (0.211), and value chain management (0.053). This result demonstrates the importance of considering the investment portfolio when implementing eco-design into shipping services, emphasizing the marketing of eco-service items, and raising staff understanding of eco-design. Lastly, the cross-functional green management criterion results indicated that the most crucial sub-criterion is responsibility fulfillment and commitment (0.387). Following this is relationship maintenance (0.337), policy establishment (0.223), and delivery environmental issues (0.063). Therefore, companies must carefully execute the plan and maintain a good link between corresponding responsibilities for the successful implementation of cross-functional green management. Of course, companies must also consider environmental concerns while developing and implementing green goals.

5 Discussion

5.1 Theoretical contributions

This study makes a lot of significant literary contributions. First, this work enriches the study of SSM and FAHP. This study constructed a comprehensive SSM operational framework, including external environment, product design, and internal management, and used the FAHP method to analyze the priority of implementing SSM, thereby filling a research gap on SSM operation from the perspective of company management strategy. According to the study, external policy pressures have a more significant impact on shipping companies' SSMs than eco-design of shipping services and cross-functional green management, which is in line with businesses reacting quickly to environmental change (Shin et al., 2017; Murillo–Avalos et al., 2021).

Second, this study advances the use of institutional theory in shipping companies. In this study, we investigated the antecedents that influence SSM using the three levels of rules and regulations, social norms, and social knowledge mentioned in institutional theory. Our findings also indicate that the most important component, followed by the eco-design of shipping services and internal cross-functional green management, is the degree to which companies implement marine-related rules and regulations. Companies that frequently break laws and regulations risk harsh penalties and even lose their reputation in an atmosphere of strictly-enforced external marine-related laws and regulations. Therefore, shipping companies must be aware of external policy influences since these outcomes impact their interests.

Third, this work advances the field of product eco-design research. This study broadens the research scope of eco-design by applying the idea to shipping businesses in the service industry, in contrast to earlier studies that concentrated on manufacturing. The investment portfolio of shipping services is undoubtedly the most crucial component in investigating specific influencing factors, followed by the value chain of shipping services, thus, the environmental practices of suppliers. Such outcomes are consistent with studies showing how business stakeholders substantially influence corporate environmental practices (Klewitz and Hansen, 2014; Kiurski et al., 2017). In addition, marketing and communication efforts should focus on delivering service products.

Fourth, this study builds on prior cross-functional management research to add to the knowledge of sustainable growth inside maritime organizations. Cross-functional cooperation from the standpoint of green management, particularly research on shipping businesses, is rarely included in existing studies, which frequently concentrate on cross-sectoral cooperation and coordination. The investigation demonstrates that cross-functional commitment and responsibility fulfillment significantly influence green management. It also indicates that setting goals is not as crucial for internal work as putting them into practice. Maintaining positive relationships between cooperative departments will be helpful for the promotion and implementation of cross-functional green management, which is another critical role of cross-functional relationships that reflects the "social attributes" of cross-functional relationships within the company.

TABLE 5 Fuzzy AHP analysis results.

Criteria	Criteria Score	Sub-criteria	Local Score	Global Score	Global Rank
Institutional pressure	0.549	IP1. Intensity of law enforcement	0.343	0.188	2
		IP2. Normative pressures	0.356	0.195	1
		IP3. Informal social knowledge	0.301	0.165	3
Eco-design for shipping services	0.288	ESS1.Incentives and awareness	0.211	0.061	7
		ESS2. Marketing and communication	0.314	0.090	5
		ESS3. Portfolio management	0.422	0.122	4
		ESS4. Value chain management	0.053	0.015	10
Cross-functional green management	0.163	CGM1. Policy establishment	0.223	0.036	9
		CGM2. Responsibility fulfillment and commitment	0.387	0.063	6
		CGM3. Relationship maintenance	0.337	0.055	8
		CGM4. Delivery environmental issues	0.063	0.010	11

5.2 Managerial implications

The study has some managerial ramifications as well. This research evaluated the sustainability of shipping firms and created a management framework for improved SSM implementation. The analysis aids in understanding the principle elements and supporting variables that influence SSM from the perspectives of three crucial business strategies: the external environment, service goods, and cross-departmental cooperation. By highlighting the most persuasive sustainability variables and their relative weight concerning other factors, the findings assist managers, strategists, and politicians in making strategic sustainability decisions.

According to the study, the external environment directly influences the implementation of SSM, which may also be related to the serious consequences that companies face after breaching laws and regulations. Although long-term legal pressure cannot solve the problem of sustainable development, shipping companies could develop a good sustainable development strategy by strengthening the implementation of relevant regulations in the short term. As a result, this study offers the government some company viewpoints regarding putting marine environmental protection laws into practice, making the creation and application of legislation more useful.

Additionally, we found two vital influencing factors: the design of the investment portfolio of shipping services and the internal commitment and fulfillment of cross-functional duties. This finding shows a crucial link between the environmental awareness of stakeholders and product design, i.e., more consideration of environmental performance in product design will be effective. Therefore, while cross-departmental cooperation should establish green goals, it should also supervise the performance of corresponding responsibilities.

By putting these sustainable development aspects into practice, shipping company managers will be better able to recognize and address challenges posed by the external environment, product design, and cross-functional management.

6 Conclusion

Existing studies lack the overall framework of SSM. Therefore, to fill the research gap, this study systematically established a general architecture for evaluating SSM from all aspects, examined SSM practices, and screened their priorities. We used the FAHP method to create 11 sub-index systems from three views: external policy pressure of shipping companies, eco-design of shipping services, and cross-functional green management within shipping companies. The findings show that external policy pressure is the most critical factor influencing sustainable shipping management, followed by eco-design and cross-functional green management. These results expand the research on sustainable shipping and related theories and serve as a basis for policy formulation by shipping industry managers and governments.

There are some gaps in this investigation. First, the framework structure of the research method's evaluation indicators still has limits. The actual situation is still confusing since shipping business operations are complex, despite that this study examined pertinent aspects from as many viewpoints as feasible. For instance, in the area of eco-design, it is more important to consider the characteristics of the service industry and identify more specific and targeted operability indicators to guide the ecological design practice of shipping enterprise services because the service industry differs from the traditional manufacturing industry. Compared to typical businesses, shipping firms have distinct functional departments. The integration and cooperation between the functional departments of shipping corporations have been the subject of focused research.

Second, this study focuses on sustainable management in the shipping industry, and the findings are applicable to research related to the shipping industry. We suggest follow-up research analysis or verification of whether this study's results apply to other fields, thus expanding the literature on sustainable management.

Third, although scholars have explored the causes of reducing shipping pollution through various methods, there is still value in analyzing the mechanisms of its impact on organizations. In the current complex business and market environment, we encourage more theories to explore sustainable shipping, including organizational information processing theory, contingency theory, dynamic capability theory, etc.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

LW: Conceptualization, methodology, writing (original draft, review, and editing). JY: Methodology, writing (original draft), resources. HZ: Writing (review and editing), resources, investigation. QP: Software, writing (original draft, review, and editing), investigation. MF: Conceptualization, methodology, investigation, formal analysis, data curation. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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