

## Article

# Toward Sustainable Shipping: Prioritizing Green Behaviors Among Ship Officers Using Delphi and Interval Type-2 F-AHP

Ramazan Ozkan Yildiz

Maritime Transportation and Management Engineering, Bandirma Onyedi Eylul University,  
Bandirma 10200, Türkiye; ramazanyildiz@bandirma.edu.tr

## Abstract

In response to the growing need for decarbonization in the maritime industry, identifying and prioritizing environmentally responsible shipboard behaviors has become increasingly important. This study proposes an integrated Delphi–Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP) framework to identify and prioritize Employee Green Behaviors (EGBs) among officer-class seafarers, who play a central role in implementing sustainability practices during daily ship operations. First, a three-round Delphi process was conducted to establish expert consensus on the most relevant green behaviors. Subsequently, IT2F-AHP was employed to prioritize these behaviors while addressing the uncertainty inherent in expert judgments. The results indicate that resource efficiency, energy conservation, and adherence to ballast water management regulations are the highest-priority behaviors for supporting sustainable ship operations. The proposed framework provides a systematic and transparent decision-support tool for shipping companies, maritime education and training institutions, and policymakers to develop targeted training programs, operational procedures, and sustainability strategies. By integrating expert consensus with advanced multi-criteria decision-making, this study contributes to the behavioral dimension of sustainable shipping and offers a practical framework for promoting the green transformation in maritime operations.

**Keywords:** employee green behavior (EGB); Delphi method; interval type 2 fuzzy analytic hierarchy process (IT2F-AHP); officer-class seafarers; sustainable shipping

## 1. Introduction

The maritime industry carries approximately 88% of world trade volume, playing a strategic role in the sustainability of global supply chains [1]. However, the sector's impacts on greenhouse gas emissions (GHG), marine pollution, and ecosystem degradation have become more intensely discussed, particularly in light of the International Maritime Organization's (IMO) First GHG Strategy and the United Nations Sustainable Development Goals (SDGs) [2]. Within this framework, sustainable maritime paradigms have gained importance as an integrated approach aiming to balance environmental protection, economic efficiency, and social responsibility [3,4].

Despite advances in technological innovations, legal regulations, and corporate sustainability strategies, the crucial element in effectively translating these goals into daily ship operations is the often-overlooked dimension of human behavior. In particular, ship officers hold a critical position as primary decision-makers in translating sustainability

Academic Editor: Kirk Chang

Received: 12 June 2026

Revised: 2 July 2026

Accepted: 4 July 2026

Published: 10 July 2026

**Copyright:** © 2026 by the author.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\) license](https://creativecommons.org/licenses/by/4.0/).

policies into operational practices [5,6]. The behaviors of officers in processes such as fuel efficiency, waste management, energy conservation, and compliance with environmental regulations directly affect the ship's environmental performance and are decisive in achieving sustainable maritime goals [7,8].

In this context, Employee Green Behavior (EGB) is gaining increasing attention in the literature as a micro-level sustainability mechanism explaining the contribution of individual behaviors to corporate environmental performance [9,10]. Encompassing both mandatory and proactive green behaviors [11], EGB is becoming even more critical in the maritime sector, where resources are limited, risk levels are high, and isolated working conditions prevail [12]. Under these conditions, environmentally conscious decision-making processes among officers are not only a preferable approach but also an operational necessity [13,14].

Previous studies on sustainable shipping have predominantly focused on technological innovations, alternative fuels, energy efficiency measures, environmental regulations, and organizational sustainability strategies as the primary drivers of maritime decarbonization and environmental performance improvement [2–8]. More recently, the literature has increasingly recognized that the successful implementation of these sustainability initiatives also depends on the environmentally responsible behaviors of shipboard personnel, thereby highlighting the importance of integrating behavioral perspectives into maritime sustainability research [9–14]. Nevertheless, existing studies have paid limited attention to systematically identifying and prioritizing the operational green behaviors of officer-class seafarers using structured, expert-based decision-support approaches.

Moreover, a review of the existing literature reveals limited attention to which green behaviors of officer-class seafarers are most critical for contributing to sustainable ship operations, what their relative importance is, and how these behaviors can be systematically prioritized. Although prior studies recognize that ship officers play a decisive role in translating sustainability policies into operational outcomes [3,5,8,14], existing research largely focuses on technological, regulatory, and organizational dimensions while providing insufficient guidance on behavior-specific prioritization in real onboard contexts. Recent sectoral assessments similarly indicate that seafarer conduct constitutes a “missing link” in the effective execution of sustainable shipping strategies and emphasize the necessity of structured, evidence-based behavioral frameworks to address this deficiency [15]. This deficiency represents a significant gap, both in the theoretical literature for structuring micro-level sustainability behaviors within the maritime context and in creating a holistic framework that provide decision support for practitioners.

In addition, recent studies have increasingly emphasized that green development and green transformation extend beyond technological innovation, financial mechanisms, and environmental policies, requiring organizations to strengthen the behavioral and organizational dimensions of sustainability implementation [16]. In particular, sustainable transformation ultimately depends on employees who translate organizational sustainability strategies into daily operational practices through environmentally responsible workplace behaviors [17]. Likewise, recent evidence indicates that leadership, organizational identity, and environmental commitment play a pivotal role in fostering employees' green behaviors and embedding sustainability into organizational culture [18,19]. Despite these advances, limited attention has been devoted to systematically identifying and prioritizing operational green behaviors among officer-class seafarers using expert-based multi-criteria decision-making approaches. Therefore, this study complements the emerging green transformation literature by providing a behavioral decision-support framework that identifies and prioritizes the green behaviors most critical to promoting sustainable shipboard operations.

To further demonstrate the scientific novelty and positioning of the present study within the existing literature, Table 1 summarizes the key differences between previous research and the proposed framework.

**Table 1.** Positioning of the present study within the existing literature.

| Aspect                                     | Existing Literature                                                                                                                                                                                               | Main Limitation in Relation to this Study                                                                                                                   | Present Study                                                                                                           |
|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Sustainable shipping and decarbonization   | Previous studies and institutional reports mainly emphasize maritime decarbonization, green shipping management, environmental regulations, energy efficiency, and technological or operational measures [1–4,6]. | These studies provide limited insight into how sustainability is operationalized through specific green behaviors performed by ship officers.               | Focuses directly on the behavioral dimension of sustainable shipping at the shipboard level.                            |
| Role of seafarers and ship officers        | Existing maritime studies acknowledge that seafarers and ship officers influence onboard environmental performance and sustainability execution [6–8,14,15].                                                      | The officer role is recognized, but officer-specific green behaviors are not systematically identified, validated, and prioritized.                         | Develops a ship-specific operational green behavior framework for officer-class seafarers.                              |
| Employee Green Behavior literature         | EGB studies explain how employee behavior, organizational support, green HRM, leadership, environmental awareness, and organizational culture contribute to sustainability [9–13].                                | Most EGB studies are grounded in general organizational or shore-based workplace contexts rather than safety-critical and regulated shipboard environments. | Contextually adapts EGB to maritime operations and officer-class seafarers' daily responsibilities.                     |
| Green development and green transformation | Recent green transformation studies emphasize that sustainability transitions require behavioral, organizational, leadership, and commitment-based mechanisms in addition to technology and policy [16–19].       | These studies rarely translate green transformation into operational behavioral priorities for maritime officers.                                           | Links green transformation to concrete shipboard behaviors and provides a behavioral decision-support framework.        |
| Methodological contribution                | Existing related studies generally provide conceptual, regulatory, technological, organizational, or behavioral explanations of sustainability and green behavior [2–19].                                         | They do not offer an integrated expert-consensus and uncertainty-based prioritization model for officer-class seafarers' green behaviors.                   | Integrates Delphi and IT2F-AHP to identify, validate, and prioritize green behaviors under expert judgment uncertainty. |
| Practical decision-support value           | Previous studies mainly offer policy, technological, managerial, or organizational recommendations for improving sustainability performance [1–8,15].                                                             | They provide limited actionable guidance on which officer-level behaviors should be prioritized in training, procedures, and performance monitoring.        | Produces a prioritized behavioral framework to support maritime companies, training institutions, and policymakers.     |

As shown in Table 1, previous studies have made substantial contributions to sustainable shipping, maritime decarbonization, green transformation, and Employee Green Behavior research. However, the existing literature has not sufficiently addressed the systematic prioritization of operational green behaviors among officer-class seafarers. The novelty of the present study lies in its integration of a ship-specific EGB perspective with a hybrid Delphi–IT2F-AHP framework. In doing so, the study moves beyond general sustainability discussions and provides a validated, uncertainty-sensitive, and practically applicable decision-support model for prioritizing green behaviors in sustainable ship operations.

The main objective of this study is to identify and prioritize the most critical employee green behaviors that support sustainable ship operations among officer-class sea-

farers. To this end, the study uses the Delphi method to structure the behavior set by leveraging expert opinions and applies the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP) method in an integrated manner to reduce uncertainty and the effects of subjective evaluation. Thus, the study aims to contribute to the systematic evaluation of EGB practices for officer-class seafarers within the framework of environmental, economic, and social sustainability dimensions and to establish a reliable and contextually robust prioritization structure to support decision-makers. The findings are expected to guide policy-makers, maritime companies, and maritime education institutions in developing sustainability-oriented ship cultures.

Based on the identified research gaps, two research questions were formulated to guide the study. The first research question addresses the lack of a systematically validated set of Employee Green Behaviors specifically tailored to officer-class seafarers, while the second responds to the absence of a structured prioritization framework capable of evaluating the relative importance of these behaviors within the environmental, economic, and social sustainability dimensions. Together, these research questions provide the foundation for the proposed Delphi-IT2F-AHP framework and directly reflect the theoretical and practical gaps identified in the existing literature.

Within this framework, the study focuses on the following research questions:

*RQ1: What are the key employee green behaviors that support sustainable ship operations among officer-class seafarers?*

*RQ2: What is the relative importance of these behaviors within the context of the sustainability dimensions, and how should they be prioritized?*

The rest of the study is structured as follows: The Section 2 examines employee green behaviors and the sustainable maritime literature within the theoretical framework. The Section 3 details the research methodology and hybrid approach. The Section 4 presents the findings, and the Section 5 discusses the results and provides recommendations for application and future studies.

## 2. Theoretical Background

Sustainability theory offers a conceptual and operational framework that aims to harmonize the three fundamental elements of sustainable development: preserving ecological integrity, achieving economic sustainability, and ensuring social justice [20,21]. This tripartite structure is not only a normative approach but also a practical model that allows for the alignment of contemporary organizational strategies with environmental and social well-being [22]. The maritime sector, characterized by high carbon intensity, complex regulations, and global interdependence, faces increasing pressure to integrate sustainability principles into its policies and practices [23].

Green Shipping, considered a reflection of sustainability theory in the maritime context, refers to a systematic transformation aimed at reducing environmental impacts while increasing operational efficiency and stakeholder value [2,24]. However, achieving these goals is not limited to technological advancements or legal compliance; it also necessitates a transformation in organizational culture and, in particular, environmentally responsible behavior among officers and seafarers who manage operational decision-making processes [25].

At this point, Employee Green Behavior (EGB) constitutes the micro-level behavioral equivalent of sustainability theory. Defined as voluntary and task-related behaviors that contribute to the improvement of environmental, economic, and social sustainability outcomes [26], EGB represents the micro-based component of organizational sustainability. These behaviors are not merely symbolic attitudes; they play a decisive role in translating

sustainability principles into daily operations, especially in ship environments where hierarchical structures are prominent, safety concerns are high, and resources are limited. The literature provides strong evidence that sustainability-oriented behaviors exhibited by employees, particularly those in leadership positions, have a ripple effect on operational processes and organizational norms [9,27].

Based on this theoretical foundation, the study examines EGB practices using a three-dimensional classification: environmental, economic, and social. This classification reflects the multidimensional nature of sustainability and makes it possible to analytically track the impact of individual behaviors on organizational outcomes (see Table 2). Furthermore, this structure aligns with international sustainability reporting standards and is consistent with the performance approach that holistically evaluates the environmental, economic, and social components of the maritime sector [28,29].

**Table 2.** Classification of GHRM Practices.

| Category                     | Code | Practice            | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | References          |
|------------------------------|------|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| Environmental Sustainability | P1   | Energy Conservation | Energy conservation, a fundamental aspect of Employee Green Behavior (EGB), denotes the deliberate measures employees engage in to diminish energy usage in the workplace and promote environmental sustainability. This practice demonstrates individual ecological consciousness and collective organizational accountability, aiding in the reduction in greenhouse gas emissions and the overarching battle against climate change. Within the EGB framework, energy saving promotes operational efficiency and aligns employee behavior with the organization's sustainability objectives. | [26,27,30–34]       |
|                              | P2   | Waste Reduction     | Waste reduction, a key component of Employee Green Behavior (EGB), involves employee-initiated actions and decisions aimed at decreasing waste production and promoting sustainable workplace practices. This conduct demonstrates an organizational dedication to environmental stewardship by reducing the ecological footprint of routine operations. Waste reduction fosters the conservation of natural resources and the promotion of long-term sustainability objectives.                                                                                                                | [26,27,30–32,35–38] |
|                              | P3   | Water Conservation  | Water conservation, as a component of Employee Green Behavior (EGB), denotes employees' proactive initiatives to minimize water consumption and avert wastage in the workplace. This practice encompasses conscientious actions, including reporting leaks, utilizing water-efficient devices, and fostering awareness of responsible water consumption among peers. By conserving water, employees aid in sustainable resource management and assist firms in diminishing their environmental footprint.                                                                                       | [26,27,30,31,38–41] |
|                              | P4   | Green Office Habits | Green office habits, as an element of Employee Green Behavior (EGB), entail the implementation of ecologically sustainable routines and activities in the workplace. These practices encompass measures such as deactivating idle electronic devices, minimizing paper usage, accurately categorizing recyclables, and maxim-                                                                                                                                                                                                                                                                   | [27,33,38,40,42–44] |

|                         |    |                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------------|----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         |    | izing the use of natural light whenever feasible. By incorporating these sustainable practices into daily work routines, employees help diminish the organization's ecological footprint and promote a culture of environmental accountability. |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Economic Sustainability | P5 | Green Crafting                                                                                                                                                                                                                                  | <p>Green crafts, a facet of Employee Green Behavior (EGB), pertains to employees' initiatives to modify or adapt their work duties and work environment to promote environmental sustainability. This may entail discovering innovative, sustainable alternatives to conventional work practices, such as repurposing resources, reducing resource use, or incorporating environmentally friendly technologies into routine activities. Through eco-friendly practices, individuals voluntarily redefine their roles to align with business sustainability objectives, promoting both personnel empowerment and environmental accountability.</p> <p>[45–50]</p> |
|                         | P6 | Resource Efficiency                                                                                                                                                                                                                             | <p>Resource efficiency concerning employee green behavior pertains to the practices and actions undertaken by employees to optimize resource utilization, minimize waste, and promote sustainability within the workplace. This concept is essential to corporate strategies focused on attaining sustainable development objectives and reducing environmental impact.</p> <p>[26,27,31,38,40,41,50,51]</p>                                                                                                                                                                                                                                                     |
|                         | P7 | Paperless Practices                                                                                                                                                                                                                             | <p>Paperless practices, as an element of Employee Green Behavior (EGB), encompass employees' deliberate attempts to reduce or eradicate paper usage in routine work operations. This entails the adoption of digital tools for documentation, communication, and record-keeping to minimize paper consumption and waste. By adopting paperless processes, employees bolster organizational sustainability efforts and aid in the preservation of natural resources.</p> <p>[52–57]</p>                                                                                                                                                                           |
|                         | P8 | Sustainable Commuting                                                                                                                                                                                                                           | <p>Sustainable commuting, a facet of Employee Green Behavior (EGB), denotes the utilization of eco-friendly transportation means by employees for their journeys to and from the workplace. This includes behaviors such as carpooling, cycling, walking, utilizing public transportation, or selecting low-emission automobiles. By selecting sustainable commuting alternatives, employees contribute to the reduction in greenhouse gas emissions, alleviate traffic congestion, and advance the organization's overarching environmental and social responsibility objectives.</p> <p>[27,58–63]</p>                                                         |

|                       |     |                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                       |
|-----------------------|-----|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Social Sustainability | P9  | Sustainable Purchasing             | Sustainable purchasing, or green purchasing, is an environmentally conscious strategy that entails choosing items and services with minimal adverse effects on the environment. This approach encompasses the minimization or eradication of hazardous substances, the encouragement of recycling and reuse, and the reduction in resources during procurement. It is an essential element of EGB and significantly enhances a company's environmental performance.                                                                                                                                          | [64–70]               |
|                       | P10 | Environmental Awareness            | Environmental awareness, a key component of Employee Green Behavior (EGB), denotes employees' conscious acknowledgment of the environmental consequences of their actions and their readiness to make informed, sustainable choices in the workplace. This approach entails remaining cognizant of environmental challenges, comprehending organizational sustainability objectives, and deliberately evaluating ecological ramifications in everyday choices. By promoting environmental awareness, employees enhance a culture of sustainability and instigate positive behavioral change inside the firm. | [30,71–77]            |
|                       | P11 | Encouraging Others                 | Encouraging others, as an element of Employee Green Behavior (EGB), entails employees actively advocating for and endorsing environmentally responsible practices among their peers. This technique encompasses disseminating knowledge regarding sustainable practices, encouraging colleagues to embrace eco-friendly habits, and cultivating a shared sense of environmental accountability within the workplace. By motivating others, employees foster a supportive culture that strengthens and enhances the organization's sustainability initiatives.                                                | [9,10,26,41,71,73,78] |
|                       | P12 | Participation in Green Initiatives | Participation in green initiatives, as part of Employee Green Behavior (EGB), denotes employees' active engagement in company programs and activities designed to foster environmental sustainability. This practice encompasses participation in recycling initiatives, energy conservation programs, sustainability workshops, or corporate social responsibility (CSR) endeavors aimed at environmental stewardship. By engaging in these efforts, employees enhance the efficacy of green programs and strengthen a shared dedication to sustainable corporate practices.                                | [26,30,73,79–83]      |

---

|     |                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P13 | Environmental Mentorship | <p>Environmental mentorship, an important facet of Employee Green Behavior (EGB), is employees instructing, educating, and motivating peers to embrace ecologically sustainable activities inside the workplace. This practice encompasses disseminating knowledge, providing support for sustainable efforts, and exemplifying environmentally acceptable conduct. Employees, via environmental mentorship, promote a culture of sustainability, enhancing long-term ecological knowledge and behavioral transformation within the firm.</p> |
|-----|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

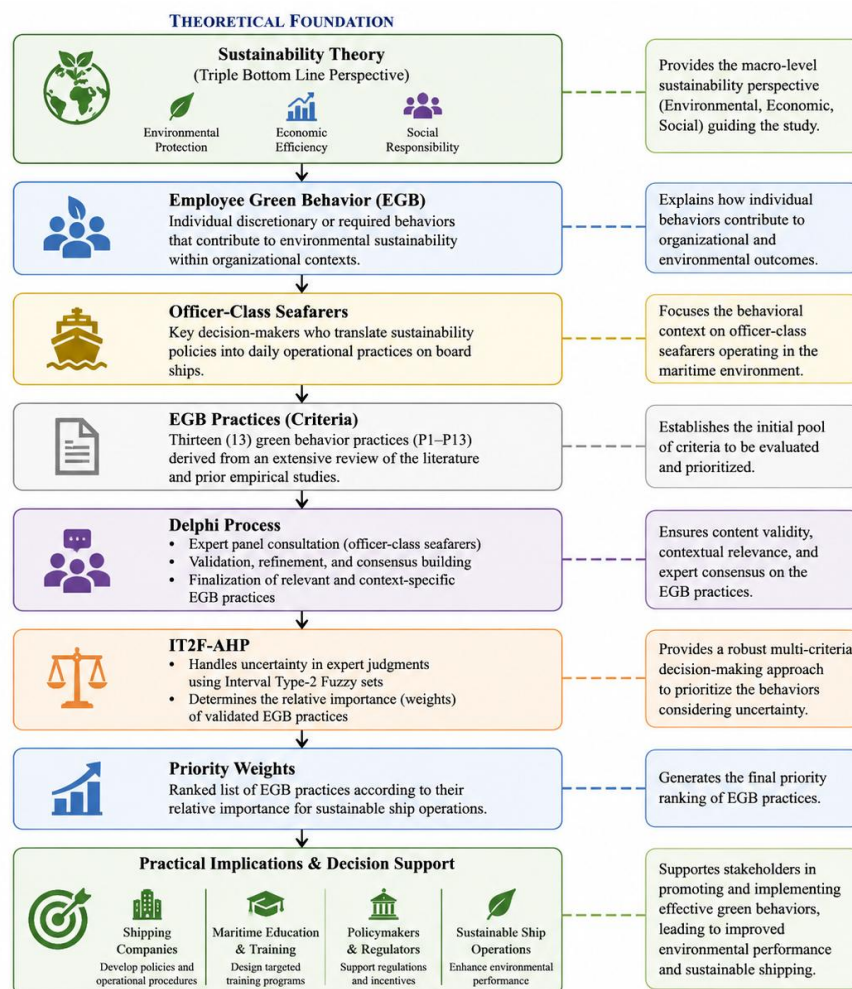
However, a review of the existing literature reveals that the issues of which green behaviors of officer-class seafarers are most critical for contributing to sustainable ship operations and how these behaviors should be prioritized are addressed in a limited way. Although previous research acknowledges the decisive role of ship officers in shaping sustainability outcomes onboard, existing studies predominantly emphasize technological advances, regulatory frameworks, and organizational-level strategies rather than systematically prioritizing behavior-specific contributions to sustainable maritime operations [5,8,13,14]. A significant portion of current studies focuses on technological and regulatory aspects; they do not adequately address behavior-based and prioritization-oriented integrated approaches, despite increasing recognition that seafarer conduct constitutes a critical “missing link” in translating sustainability strategies into operational reality [2,15]. This indicates a significant gap, both at the theoretical level and in practice.

In this context, the integrated consideration of sustainability theory and employee green behavior concepts explains how macro-level sustainability goals are embodied through micro-level behavioral outcomes and provides a theoretical foundation for the methodological choices of the study. Within this framework, the Delphi method is used to structure the expert-based behavior set, and the Interval Type-2 Fuzzy Analytic Hierarchy Process is used to prioritize behaviors by reducing uncertainty; thus, a theoretically grounded and methodologically consistent evaluation framework is established.

To establish a clearer link between the theoretical background and the methodological framework, Figure 1 presents the conceptual framework underpinning the study. The framework illustrates how Sustainability Theory and the Employee Green Behavior (EGB) perspective provide the theoretical foundation for identifying officer-specific green behaviors, which are subsequently refined through the Delphi process and prioritized using the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP). This integrated framework forms the basis of the proposed decision-support model for promoting sustainable ship operations.

Figure 1 illustrates the conceptual framework underpinning the present study by linking its theoretical foundations with the proposed methodological approach. The framework demonstrates how Sustainability Theory, through its environmental, economic, and social dimensions, provides the overarching perspective for evaluating sustainable ship operations, while the Employee Green Behavior (EGB) framework explains the behavioral mechanisms through which individual actions contribute to organizational environmental performance. Building upon these theoretical foundations, green behaviors specific to officer-class seafarers are identified from the literature and subsequently refined through expert consensus, validated through the Delphi process, and prioritized using the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP). The resulting prioritization framework provides a structured decision-support tool to guide maritime

companies, training institutions, and policymakers in promoting sustainable ship operations.



**Figure 1.** Conceptual framework linking Sustainability Theory, Employee Green Behavior, the Delphi process, and the IT2F-AHP prioritization framework.

### 3. Conceptual Background

#### 3.1. Employee Green Behavior (EGB)

Employee Green Behavior (EGB) is a critical concept that represents the intersection of individual behaviors with organizations' sustainability goals [90]. As a comprehensive framework, EGB includes individual actions that contribute to reducing environmental damage through practices such as energy conservation, waste reduction, efficient resource use, and raising environmental awareness [91]. These behaviors play a fundamental role in embedding sustainability into organizational culture and shaping corporate environmental identity.

The effectiveness of EGB is closely related to how employees perceive their organizations' genuine commitment to sustainability. Hsieh and Wang (2015) [92] show that employees' tendency to participate in environmentally responsible behaviors increases significantly when they perceive sustainability initiatives as realistic and consistent. Similarly, drawing from the framework of Planned Behavior Theory, Khalid et al. (2022) [39] emphasize that organizational support is crucial in transforming environmental intentions into lasting behaviors; they state that perceived norms and a sense of control have a critical mediating effect in this process.

Green Human Resource Management (GHRM) practices offer important leverage mechanisms for promoting and institutionalizing EGB. Including environmental metrics in performance appraisal systems and integrating sustainability components into decision-making processes strengthens employee participation in environmental initiatives [93]. Aukhoon et al. (2024) [51] show that voluntary environmental actions by employees significantly increase in organizations with an environmentally focused strategic orientation; this confirms the transformative effect of a strong green organizational culture on employee behavior.

Understanding environmental sustainability values requires considering not only organizational structures but also psychological and emotional processes. Findings indicating that changes in daily positive emotional levels directly affect employees' environmental behavior [94] demonstrate the necessity of evaluating intrinsic motivation, personal values, and identity perception together with external organizational factors. In this context, aligning reward mechanisms with sustainability values stands out as a fundamental element supporting the continuity of environmentally friendly behavior [17,95].

The literature also emphasizes that the psychological connection employees establish with their organization's environmental identity is one of the strongest determinants of EGB. Bhattacharya et al. (2022) [96] state that employees who internalize organizational environmental values show a higher level of participation in sustainability practices. In this context, empowerment mechanisms that enable employees to perceive their environmental contributions as meaningful and effective increase intrinsic motivation and encourage lasting behavioral change [97]. Therefore, EGB is not a one-dimensional and static phenomenon; it is a multi-layered behavioral structure shaped by the interaction of organizational support, cultural structure, leadership styles, and individual agency [98,99].

EGB has evolved from a marginal area of initiative to a strategic necessity for sustainability-focused organizations [11]. Organizations can promote widespread pro-environmental behaviors by integrating corporate support, coherent incentive mechanisms, psychological empowerment, and cultural entrenchment within a holistic framework, thereby supporting not only corporate social responsibility goals but also global environmental sustainability objectives [100].

Employee Green Behavior consists of voluntary actions in the workplace that directly or indirectly support environmental sustainability. These actions go beyond formal job descriptions and reflect employees' individual commitment to reducing ecological damage, increasing resource efficiency, and fostering a culture of environmental responsibility [26,27]. Therefore, EGB serves as a critical bridge in translating organizational sustainability policies into tangible operational outcomes, transforming employees from passive implementers to active carriers of sustainability goals [30,31]. In this context, EGB practices are classified under the dimensions of environmental, economic, and social sustainability, encompassing behaviors such as energy conservation, waste reduction, green work habits, sustainable transportation choices, and environmental mentoring [9,32,40,58,84]. This classification allows for a systematic explanation of how individual behaviors align with organizational sustainability goals.

Especially in high-risk, heavily regulated, and operationally complex sectors like maritime shipping, Environmental Performance Certificates (EPCs) are becoming an increasingly critical tool for mitigating environmental risks and aligning daily operations with sustainability principles [2,28]. However, a review of the existing literature reveals limited attention to which green behaviors of officer-class seafarers are most effective for contributing to sustainable ship operations and how these behaviors should be prioritized. Although previous studies acknowledge that ship officers play a decisive role in shaping sustainability outcomes onboard [5,8,13,14], a significant portion of the existing literature continues to focus predominantly on technological developments, regulatory

mechanisms, and organizational-level sustainability strategies rather than systematically prioritizing behavior-specific contributions. Recent sectoral assessments further emphasize that seafarer behavior remains a critical “missing link” in translating sustainability strategies into operational reality, highlighting the need for structured, evidence-based behavioral frameworks in maritime contexts [2,15]. This indicates a significant gap both at the theoretical level and in practice.

Based on this point, a systematic classification and prioritization of the behavioral set requirements are necessary. This study aims to address this gap by utilizing the Delphi approach to structure the behavioral set based on expert opinions, and the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP) method to determine the relative importance of behaviors while reducing uncertainty and subjective evaluation effects. This approach provides a robust evaluation framework that is both theoretically grounded and practically applicable.

Table 2 presents the classification of Employee Green Behavior (EGB) practices within the tripartite sustainability framework comprising environmental, economic, and social dimensions. This taxonomy systematizes EGB into distinct yet interrelated, categories that reflect how individual employee actions contribute to broader sustainability outcomes at the organizational level. The environmental dimension encompasses behaviors aimed at minimizing ecological footprints through energy conservation, waste reduction, water efficiency, and eco-friendly workplace habits. The economic dimension emphasizes practices that enhance efficiency, reduce operational costs, and support resource optimization, while the social dimension highlights behaviors that foster environmental awareness, collective engagement, and the cultural reinforcement of sustainability norms. This structured classification not only aligns with international sustainability reporting perspectives but also enables a more precise evaluation, prioritization, and strategic integration of EGB practices into organizational sustainability agendas, particularly in sectors where environmental performance is operationally critical, such as the shipping industry. Although these practices originate from the general EGB literature, they were refined and validated through a Delphi process to ensure their operational relevance for officer-class seafarers under real shipboard conditions.

### 3.2. Employee Green Behavior Practices Among Officer-Class Seafarers

In the context of maritime sustainability, officers play a critical role as both implementers and facilitators of environmentally sound practices on board ships [101]. Through their decision-making authority, technical expertise, and operational oversight responsibilities, officers have the power to directly shape the environmental impact of ship operations and the behavioral norms of the crew under their management [102,103]. Therefore, institutionalizing Employee Green Behavior (EGB) within this group becomes a strategic necessity, going beyond individual responsibility and strengthening corporate commitment to sustainable maritime transport [104]. Officer-level commitment to energy conservation, waste reduction, environmental compliance, and responsible operational practices forms the behavioral foundation of an environmentally conscious maritime culture.

While Employee Green Behavior (EGB) has traditionally been conceptualized in office-based, manufacturing, and service sector organizations, its application in the maritime industry requires important contextual adaptation. Unlike conventional workplaces, shipboard environments are characterized by strict operational hierarchies, safety-critical tasks, limited resources, and internationally regulated environmental requirements. Consequently, officer-class seafarers do not merely exhibit generic workplace green behaviors; rather, they perform environmentally responsible operational behaviors that are directly associated with navigation, machinery operation, pollution prevention, resource management, and compliance with international maritime regulations. Therefore, the behaviors

examined in this study should not be regarded as direct adaptations of conventional EGB practices. Instead, they represent ship-specific operational green behaviors that were systematically identified through the literature, refined via a three-round Delphi process, and prioritized using the IT2F-AHP approach to accurately reflect the unique environmental responsibilities and decision-making roles of officer-class seafarers in sustainable ship operations [5,13,26,101–106]. Consequently, the resulting behavioral framework reflects operational practices that officer-class seafarers can directly influence through their daily navigational, engineering, supervisory, and environmental management responsibilities. Accordingly, the prioritized behaviors identified in this study should be interpreted as operational sustainability practices embedded in officers' daily shipboard responsibilities rather than as generic workplace environmental behaviors.

Given the increasingly complex nature of modern maritime transport, the adoption of Environmental Conformity Practices (ECPs) by officers is becoming even more critical. Compliance with environmental standards directly impacts navigation, technical operations, and daily decision-making processes, creating a structure where environmentally responsible behaviors are directly linked to operational outcomes [24]. Examples of officers adopting sustainable maintenance practices, promoting environmentally friendly work habits in bridge and engine control environments, and optimizing voyage planning to reduce emissions demonstrate that behavioral interventions can translate sustainability principles into measurable results [33,71]. These practices are consistent with the core principles of Green Shipping and strengthen regulatory compliance, operational efficiency, and environmental responsibility [105].

Environmental practices initiated by officers also play a decisive role in shaping the environmental identity of maritime enterprises. In ship environments where hierarchy is pronounced, pressure is high, and space is limited, officer behaviors have a multiplier effect; consistently exhibited green behaviors at the officer level encourage the development of collective participation across different crew strata. Officers who implement practices such as sustainable resource use, responsible procurement, participation in environmental initiatives, and environmental mentoring are positioned as cultural carriers, bridging the gap between sustainability policies and reality on deck [26,106]. In this context, the role of officers is not only operational but also symbolic; they represent sustainability from the bridge to the engine room of the ship.

However, a review of the existing literature reveals that the issues of which EGB practices among officer-class seafarers contribute most to sustainable ship operations and how these behaviors should be prioritized are only minimally addressed. A significant portion of the studies focuses on technological advancements, regulations, or institutional-level strategies; behavior-based and prioritization-oriented frameworks specific to the maritime context are not adequately explored. This situation points to a critical gap, both theoretically and practically, in a sector where environmental performance is directly linked to daily operational behaviors.

This study aims to systematically identify and prioritize EGB practices among officer-level seafarers to address the aforementioned gap. To this end, the Delphi approach was used to structure the behavior set, drawing on expert opinions, and the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP) was applied to determine the relative importance of the behaviors by managing uncertainty and subjective evaluation effects. Thus, the study provides a theoretically grounded and methodologically consistent decision-making framework for evaluating officer-level green behaviors in the context of maritime operations. This hybrid methodological approach is discussed in detail in the following section.

## 4. Methodology

### 4.1. Research Approach and Process

This study aims to identify and prioritize Employee Green Behavior (EGB) practices for officer-class seafarers to support environmentally responsible and sustainability-oriented ship operations. To achieve this goal, a structured hybrid methodology was adopted, integrating the Delphi technique with the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP). This framework enables the systematic transition from expert consensus building to quantitative prioritization under uncertainty, ensuring both methodological rigor and contextual relevance.

In the first phase, the Delphi method was applied to refine and validate the initially identified EGB practices. Delphi is widely acknowledged as an appropriate technique for addressing complex, context-dependent decision problems and for systematically consolidating expert knowledge through iterative consultation processes [107–109]. Its suitability for maritime sustainability assessment is further supported by prior applications in maritime environmental performance evaluations [110]. The iterative structure of Delphi facilitates structured feedback, the reduction in bias, and progressive convergence toward expert consensus, thereby enhancing the validity and credibility of the final behavioral set.

Following consensus establishment, the second phase employed the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP) to determine the relative importance of the validated EGB practices. Classical AHP effectively structures hierarchical decision problems but assumes precise judgments, which is rarely realistic in high-risk operational environments such as shipping. Fuzzy AHP extends this capability by embedding uncertainty into pairwise comparisons [111,112]. However, since maritime sustainability decisions inherently involve linguistic ambiguity, expert variability, and higher-order uncertainty, Interval Type-2 fuzzy sets offer a superior solution by capturing a spectrum of possible values rather than single-point estimates, thus improving robustness and reliability [111,113,114].

Recent studies also confirm that IT2F-AHP is an effective tool for sustainability-oriented multi-criteria evaluations in complex operational contexts [115–117].

The research process followed a sequential design. First, a comprehensive literature review was conducted to identify a broad pool of potential EGB practices applicable to maritime contexts. These practices formed the input for a multi-round Delphi study, through which expert feedback was iteratively evaluated and consolidated, resulting in a final validated set of 12 EGB practices. In the subsequent phase, IT2F-AHP was applied to derive priority weights for these practices, incorporating uncertainty and expert subjectivity into the decision process to produce a credible and realistic prioritization scheme.

This hybrid Delphi–IT2F-AHP framework therefore combines expert-driven contextual insight with advanced decision-analytic rigor, ensuring that the resulting prioritization supports both theoretical advancement and practical decision-making in sustainable maritime operations. Figure 2 presents the research flowchart, illustrating the sequential phases and interactions among the methodological steps.



**Figure 2.** Research Flowchart.

#### 4.2. Delphi Process

This study employed the Delphi method to identify, refine, and validate the most appropriate Employee Green Behavior (EGB) practices for officer-class seafarers within the tripartite framework of environmental, economic, and social sustainability. The Delphi technique was considered particularly suitable due to its iterative and structured nature, its strong capability to integrate expert knowledge into complex decision contexts, and its ability to facilitate consensus-building under uncertainty [118]. Through controlled feedback and anonymity, it reduces group pressure, prevents dominance bias, and supports independent expert judgment, which is especially relevant in hierarchical and authority-driven sectors such as maritime shipping [119].

In the maritime domain, organizational hierarchies and principal–agent dynamics may restrict open expression of views in conventional group settings. Therefore, Delphi offers a confidential and neutral platform enabling experts to articulate experience-based, operationally realistic, and contextually grounded evaluations [120]. The technique has been increasingly applied in shipping research to address multifaceted and uncertain decision environments, including decarbonization policies, port sustainability transitions, fleet optimization, and maritime operational strategy development [121–124]. Building upon this methodological tradition, Delphi was adopted in the present study to ensure that the identified EGB practices are not only theoretically sound but also feasible, actionable, and meaningful within real shipboard conditions.

The data collection procedure included a survey based on Google Forms, using a 7-point Likert scale items to evaluate each activity. The software facilitated a tailored landing page that educated participants with the research technique. The system automatically adjusted the layout according to the quantity of objects addressed and integrated input validation mechanisms to guarantee response precision, such as mandating numeric entries within a certain range of 1 to 7 (see Table 3).

The survey underwent a thorough expert evaluation to improve the instrument’s reliability and content validity. This process engaged five scholars from various institutions:

an Associate Professor from Dokuz Eylul University, a Professor and an Assistant Professor from the University of Piraeus, an Associate Professor from Ankara Science University, and an Assistant Professor from Bursa Technical University. The reviewers assessed the relevance, clarity, and comprehensiveness of the items in accordance with the study's aims. Additionally, two previous ship officers with academic qualifications engaged in the pilot testing of the questionnaire. Follow-up interviews were administered one week apart, and the consistency of their responses across both sessions validated the instrument's robustness and interpretative clarity.

**Table 3.** Statements of Delphi Scale.

| No | Statement            | Meaning                                                                                           |
|----|----------------------|---------------------------------------------------------------------------------------------------|
| 1. | Not Relevant         | The practice is not applicable or necessary for the shipping industry.                            |
| 2. | Slightly Relevant    | The practice has very limited applicability or relevance to the shipping industry.                |
| 3. | Somewhat Relevant    | The practice has limited applicability but may have some minor benefits.                          |
| 4. | Moderately Relevant  | The practice is somewhat applicable and could moderately impact the shipping industry.            |
| 5. | Very Relevant        | The practice is highly applicable and has a significant positive impact on the shipping industry. |
| 6. | Extremely Relevant   | The practice is crucial and has a profound impact on the shipping industry.                       |
| 7. | Absolutely Essential | The practice is essential for promoting sustainability in the shipping industry.                  |

#### 4.3. Delphi Panel and Rounds

Panelist selection was conducted using purposive sampling, which is widely recommended in Delphi studies where the objective is not statistical representativeness but the inclusion of knowledgeable individuals capable of providing domain-specific, experience-based, and evaluative judgments [107,108]. In line with best practices in expert-driven decision research, purposive sampling allows the intentional recruitment of participants who possess demonstrable expertise, operational familiarity, and contextual competence regarding maritime sustainability and shipboard behavioral practices [125]. This approach ensures that the Delphi outcomes reflect qualified judgment rather than random opinion, thereby enhancing content validity and methodological rigor. Similar sampling logic has been successfully applied in maritime and sustainability-focused Delphi studies, confirming its suitability for complex, context-dependent decision environments [110,121].

The recruitment process followed a structured purposive sampling strategy to ensure the inclusion of experts with demonstrable seafaring competence, managerial insight, and contextual familiarity with sustainability-related shipboard practices. In line with Delphi best-practice recommendations, the objective was not statistical representativeness, but the intentional selection of highly knowledgeable individuals capable of providing qualified judgments [107,108]. Eligible participants were required to meet the following criteria: (i) a minimum of three years of professional experience as officer-class seafarers, (ii) prior service in key operational positions such as deck or engineering officers with responsibility for decision-making in navigation, machinery management, or safety–environmental compliance, and (iii) demonstrable familiarity with sustainability practices, environmental performance requirements, or green operational procedures onboard ships. Although the panel included maritime academics, all academic members possessed substantial prior sea-going experience as licensed officers, thereby ensuring that their perspectives were grounded in real shipboard practice rather than purely theoretical understanding.

To enhance the representativeness of operational realities, care was taken to maintain diversity across rank categories (e.g., Second Officer, Chief Officer, Chief Engineer, and Master) and ship types (e.g., container vessels, tankers, and bulk carriers), ensuring a balanced cross-section of expertise. Participants without direct operational responsibilities, insufficient sea-time, or limited exposure to environmental management practices were excluded. This structured yet selective recruitment ensured that the Delphi panel reflected both operational expertise and strategic competence, thereby reinforcing methodological rigor and content validity in line with previous expert-based maritime decision studies [110,121].

The composition of the expert panel was intentionally designed to ensure a comprehensive evaluation of green behaviors among officer-class seafarers from operational, managerial, and academic perspectives. Importantly, all Personnel Managers and Maritime Academics included in the panel had previously served as officer-class seafarers before transitioning to shore-based managerial or academic positions. Consequently, every expert possessed substantial firsthand shipboard operational experience. Personnel Managers contributed insights into the environmental competencies and green behaviors expected by shipping companies, whereas Maritime Academics provided theoretical and sustainability-oriented perspectives informed by maritime research. Masters, Chief Engineers, and active Deck and Engine Officers contributed their current operational expertise and practical shipboard experience. Furthermore, both deck and engine officers were deliberately included to ensure a holistic evaluation across the two principal operational departments onboard ships, recognizing that sustainable ship operations require the integration of navigational and engineering functions. Therefore, this multidisciplinary composition strengthened the content validity of the behavioral framework while ensuring that the identified behaviors remained representative of officer-class seafarers' operational green behaviors.

The size of the Delphi panel was determined in accordance with established methodological recommendations and recent applications in maritime sustainability research. Unlike survey-based research, the Delphi technique does not require statistically representative samples; instead, its methodological rigor depends primarily on the expertise, diversity, and relevance of the selected panel members. Accordingly, previous methodological studies have consistently emphasized that relatively small, purposefully selected expert panels are sufficient for achieving reliable consensus in specialized research contexts. Okoli and Pawlowski (2004) recommend panels comprising approximately 10–18 experts [107], while Paré et al. (2013) argue that excessively large panels may reduce the efficiency of consensus building without necessarily improving the quality of expert judgments [108]. More recently, Strasser (2017) further emphasized that the credibility of Delphi studies is determined by the quality of expert selection, iterative feedback, anonymity, and controlled consensus development rather than by the absolute number of participants [126]. Likewise, recent Delphi-based methodological research has confirmed that expert panels consisting of approximately 8–15 participants are generally adequate when panel members possess substantial domain expertise and homogeneous professional competence [127].

The 12-member Delphi panel adopted in this study fully satisfies these methodological recommendations. All panel members possessed extensive professional experience in the maritime sector and were selected based on predefined eligibility criteria to ensure high levels of operational knowledge, managerial competence, and academic expertise. Furthermore, the selected panel size is consistent with recent expert-based maritime studies employing Delphi and expert consensus methodologies. For example, Laine et al. (2024) developed a maritime risk maturity model through a Delphi process with maritime risk management experts [128], while Bostoughli and Saraceni (2025) employed a two-

round Delphi study with European port experts to evaluate the transferability of green port strategies [129]. Similarly, Arıcan et al. (2025) applied a Fuzzy Delphi-based framework to identify the critical impacts of carbon regulations on the maritime sector using expert judgments [130]. Moreover, Govindan et al. (2024) established a research agenda for enabling net-zero shipping by prioritizing techno-economic and policy research challenges through consultations with a diverse panel of maritime experts, further demonstrating the widespread application of expert-based approaches in contemporary maritime sustainability research [131]. These recent studies demonstrate that carefully selected expert panels of comparable size are widely accepted and methodologically appropriate for addressing complex decision-making problems in maritime sustainability research.

Table 4 delineates the professional and demographic profiles of the twelve experts who engaged in the Delphi panel, chosen by purposeful sampling to guarantee substantial sectoral expertise and contextual pertinence. The panel consisted of a balanced combination of shipboard commanders and shore-based personnel managers, representing a varied range of vessel types (tankers, tugboats, bulk carriers, etc.). This diversity guaranteed that the green behavior practices being evaluated were analyzed from several operational viewpoints. The participants occupied senior ship officers, including ocean-going masters, chief officers, second engineers, and HR managers—roles that involve both operational and personnel-related decision-making authority. Their professional experience varied from 3 to 22 years, with most having over a decade of expertise in shipping operations or human resource roles, thus enhancing the panel’s combined practical knowledge. Moreover, the educational qualifications of the experts were very robust; five possessed PhD degrees, three had attained master’s degrees, and the rest held bachelor’s degrees. Despite the panel’s largely male composition, it featured two female officers in technically challenging positions, providing crucial gender-based insights within a male-dominated field. The makeup of the Delphi panel demonstrates significant academic and practical expertise, guaranteeing the credibility and contextual relevance of the consensus achieved regarding Employee Green Behavior practices in the shipping industry.

**Table 4.** Profile of the Delphi respondents.

| Expert No | Ship Type                    | Position                    | Years of Experience in HR/Logistics | Gender | Education         |
|-----------|------------------------------|-----------------------------|-------------------------------------|--------|-------------------|
| 1         | Bulk Carrier                 | Personnel Manager           | 15                                  | Male   | Master’s Degree   |
| 2         | Tugboat                      | Ocean-Going Second Engineer | 10                                  | Female | Bachelor’s Degree |
| 3         | Drillship                    | Ocean-Going Master          | 15                                  | Male   | PhD               |
| 4         | Tanker                       | Ocean-Going Second Engineer | 6                                   | Male   | PhD               |
| 5         | Bulk Carrier, Container Ship | Ocean-Going Watch Officer   | 3                                   | Male   | Bachelor’s Degree |
| 6         | Bulk Carrier                 | Ocean-Going Second Engineer | 5                                   | Male   | PhD               |
| 7         | Bulk Carrier                 | Ocean-Going Watch Engineer  | 12                                  | Male   | PhD               |
| 8         | Bulk Carrier                 | Ocean-Going Chief Officer   | 15                                  | Male   | Bachelor’s Degree |
| 9         | Chemical Tanker              | Personnel Manager           | 22                                  | Male   | Bachelor’s Degree |
| 10        | Tanker                       | Personnel Manager           | 17                                  | Male   | Master’s Degree   |
| 11        | Tanker                       | Ocean-Going Master          | 10                                  | Male   | Master’s Degree   |
| 12        | Tanker                       | Ocean-Going Chief Officer   | 14                                  | Female | Bachelor’s Degree |

Each consenting expert received a personalized invitation via email, which outlined the study’s objectives, methodological approach, and included a secure link to the survey

platform. Prior to initiating the questionnaire, participants were asked to provide contextual information regarding their professional expertise and current organizational affiliation. In the first round of the Delphi process, participants were invited to assess the relevance of 13 pre-identified Employee Green Behavior (EGB) practices (see Table 2) extracted from a comprehensive review of related literature using a 7-point Likert scale, as defined in Table 3.

In the first round, consensus was reached on three of the proposed practices (*Waste Reduction, Green Office Habits and Encouraging Others*) while the remaining ten did not meet the predefined agreement threshold. Respondents were also given the opportunity to offer qualitative feedback or suggest additional criteria. Alongside the quantitative consensus established through multiple Delphi rounds, a comprehensive content analysis of participants' open-ended responses was performed to reveal nuanced insights into the contextual relevance and perceived obstacles to implementing green behaviors in ship operations. The analysis included a systematic coding technique based on both deductive and inductive methodologies. The responses were classified into three primary thematic domains: (1) priority areas for the adoption of environmentally sustainable behaviors (e.g., energy efficiency, water conservation, waste management), (2) structural and operational limitations (e.g., restricted control over procurement, obligatory use of single-use materials for hygiene), and (3) facilitating mechanisms, including training, leadership, and incentive systems. A recurring theme in the comments was the essential role of deck officers in merging environmental compliance with operational performance, particularly in ballast water management, eco-speed navigation, and MARPOL-regulated waste segregation. Furthermore, acknowledging the constraints dictated by inspection mandates and regulatory documentation, such as the infeasibility of entirely paperless systems, illustrates the intricate relationship between policy and practice at sea.

Qualitative content analysis was systematically employed to assess the open-ended replies obtained during the initial Delphi round, in accordance with the methodological guidelines established by Mayring (2000) [132], Krippendorff (2004) [133], and Elo and Kyngäs (2008) [134]. The analytical procedure comprised four meticulous stages: data preparation, open coding, categorization, and abstraction. Initially, all narrative replies were meticulously examined to guarantee comprehensive immersion and familiarity with the situation. Key terms were inductively categorized and arranged into theme clusters, representing established characteristics of environmental, economic, and social sustainability. This inductive reasoning was underpinned by both theoretical principles and sector-specific significance [135]. The coding technique was perpetually enhanced to guarantee internal consistency and conceptual coherence. The preservation of transparency and analytical precision throughout the procedure improved the confidence and reliability of the findings. This strategy facilitated the creation of a significant behavioral framework for green behaviors among deck officers, while also addressing the practical limits, expectations, and sustainability priorities pertinent to the shipping industry [136].

As a direct outcome of the content analysis conducted following the first Delphi round, participants proposed the addition of *Adhering to Ballast Water Management Regulations* as a distinct behavioral criterion, underscoring its ecological relevance and operational sensitivity in maritime contexts. This criterion was subsequently incorporated into the second-round Delphi survey, exemplifying the analytical value of integrating open-ended expert feedback into structured consensus-building methods.

Building upon this analysis, the second Delphi round incorporated the ten practices that had not achieved consensus in the first round, along with an additional item, *Adhering to Ballast Water Management Regulations*, which emerged from the qualitative content analysis of expert comments. This brought the total to eleven items under evaluation in the second round. Notably, the criterion related to ballast water management quickly attained

consensus, emphasizing its operational and ecological salience. Additionally, consensus was reached on the inclusion of five other EGB practices: *Energy Conservation*, *Water Conservation*, *Resource Efficiency*, *Sustainable Purchasing*, and *Environmental Awareness*. Conversely, *Sustainable Commuting* was excluded based on strong agreement regarding its lack of contextual relevance in shipboard environments. At the end of this round, four practices still failed to reach consensus, reflecting continued divergence in expert perspectives and necessitating a third and final round of evaluation.

During the interval between the rounds, all experts received anonymized summary feedback, which included median scores and interquartile ranges (IQRs) for each item. This facilitated their reflection on the group's collective evaluations and allowed for the revision of prior judgments if considered necessary, a fundamental tenet of iterative Delphi methodology [137,138]. This organized feedback system was the principal method for settling disputes, guaranteeing that differing viewpoints were harmonized by educated reassessment instead of coerced agreement. Participants were able to compare their judgments with the group medians and interquartile range dispersion levels, fostering introspection and cognitive alignment devoid of interpersonal bias. Consensus was operationally defined as an interquartile range (IQR) of  $<1$  and a median score of  $\geq 4$  on the 7-point Likert scale, criteria often accepted in Delphi studies for achieving a balance between rigor and inclusivity [110,138]. This repeated feedback loop ensured a methodologically transparent, data-driven reconciliation of differing opinions, enhancing both the legitimacy and trustworthiness of the final agreement.

In the third and final round, these four unresolved practices were re-evaluated. Expert panelists achieved consensus on the inclusion of *Green Crafting*, *Paperless Practices*, and *Environmental Mentorship*, affirming their relevance to officer-class seafarers. In contrast, *Participation in Green Initiatives* was excluded based on expert agreement, likely due to limited structural opportunities for such engagement in maritime settings or its perceived detachment from core officer responsibilities.

Ultimately, the Delphi process yielded a refined set of 12 EGB practices, grounded in both empirical evidence and expert validation. This methodologically rigorous and context-aware selection enhances the framework's ecological validity and ensures its alignment with the lived realities of maritime professionals. The integration of qualitative and quantitative insights reinforces the framework's potential utility in informing policy development, crew training programs, and operational strategies aimed at advancing sustainability in the shipping industry.

Following the completion of the Delphi process, the initial literature-derived pool of fourteen Employee Green Behavior (EGB) practices was systematically refined based on predefined consensus criteria (median  $\geq 5$  and IQR  $\leq 1$ ), together with expert recommendations obtained during the iterative evaluation rounds. Accordingly, twelve practices satisfied the consensus requirements and were retained for the subsequent IT2F-AHP analysis, whereas two practices (P8: Sustainable Commuting and P12: Participation in Green Initiatives) were excluded because expert consensus indicated that they lacked sufficient operational relevance and contextual applicability to officer-class seafarers' onboard responsibilities. In contrast, "Adhering to Ballast Water Management Regulations" (P14), which emerged from expert recommendations during the Delphi process, was incorporated into the final framework because of its recognized operational significance for sustainable ship operations and compliance with international maritime environmental regulations. Consequently, the validated set of twelve EGB practices was transferred without further modification to the IT2F-AHP stage, ensuring methodological consistency between the qualitative consensus-building process and the quantitative prioritization analysis.

The reliability of the Delphi instrument was assessed using Cronbach's Alpha, yielding a value of 0.626. This indicates an acceptable level of internal consistency among the evaluated Employee Green Behavior (EGB) practices, particularly given the exploratory nature of the study and the interdisciplinary composition of the expert panel. Although not very high, this level aligns with thresholds considered adequate in early-stage research within the social sciences and Delphi-based investigations, where moderate reliability scores are frequently reported due to the heterogeneous nature of expert panels and the complexity of behavioral constructs [118,137,139]. In this regard, the obtained alpha value reflects both methodological adequacy and the inherent diversity of expert perceptions across different shipboard roles and sustainability dimensions.

Moreover, it should be noted that the objective of the present Delphi instrument was not to measure a single latent construct but rather to evaluate a diverse set of operational Employee Green Behaviors spanning environmental, economic, and social sustainability dimensions. Consequently, extremely high internal consistency would not necessarily be expected, as the evaluated behaviors intentionally represent conceptually distinct operational practices rather than highly homogeneous measurement items. Therefore, the obtained Cronbach's Alpha value should be interpreted within the context of exploratory Delphi research involving heterogeneous expert panels and multidimensional behavioral constructs rather than according to the standards typically applied to psychometric scale development.

Furthermore, Kendall's W, a widely recognized measure of inter-rater agreement in Delphi studies, was calculated as 0.450, indicating a moderate level of consensus among participants. While this does not suggest complete uniformity, such values are commonly observed in Delphi research dealing with complex, context-specific, and multi-dimensional issues such as sustainability-related maritime practices [138,140]. Hasson et al. (2000) [137] emphasize that moderate agreement levels are to be expected in expert-driven Delphi panels, particularly when the panel intentionally incorporates diverse professional backgrounds to enrich judgment quality rather than to enforce artificial homogeneity.

To further strengthen the reliability assessment, Kendall's W was complemented with Interquartile Range (IQR) analysis, which is widely endorsed in Delphi methodology as a granular and robust indicator of consensus [138]. Most of the assessed practices produced IQR values of  $\leq 1$ , demonstrating limited dispersion in expert evaluations and reinforcing the presence of meaningful convergence despite varied professional perspectives. This dual-indicator strategy mitigates the effect of statistical outliers and provides a more nuanced depiction of agreement than Kendall's W alone. In line with established Delphi protocols, consensus in this study was defined as an IQR  $\leq 1$  combined with a median score  $\geq 5$  on a 7-point Likert scale [110,138]. The complementary use of Cronbach's Alpha, Kendall's W, and IQR therefore ensured methodological triangulation and analytical rigor, confirming that the Delphi process achieved a reliable and credible level of consensus. Table 5 summarizes the final Delphi outcomes, where low IQR scores substantiate the stability and convergence of expert judgments.

It should also be emphasized that Cronbach's Alpha and Kendall's W assess different methodological characteristics of Delphi studies and therefore should not be interpreted using identical evaluation criteria. While Cronbach's Alpha measures the internal consistency of the evaluation instrument, Kendall's W assesses the degree of agreement among experts. Since the primary objective of the Delphi technique is to establish expert consensus rather than validate a psychometric measurement scale, consensus indicators such as Kendall's W, median values, and IQR are considered more informative than Cronbach's Alpha alone. Accordingly, the combined interpretation of Cronbach's Alpha, Kendall's W, median values, and IQR demonstrates that the Delphi process achieved an

acceptable level of methodological rigor, reliability, and expert consensus for developing the proposed behavioral prioritization framework.

**Table 5.** Delphi Process Final Results.

| Practice Code | Mean ( $\bar{x}$ ) | Median | IQR  | Consensus/Consensus Round | Inclusion |
|---------------|--------------------|--------|------|---------------------------|-----------|
| P1            | 5.00               | 5      | 0    | +2                        | +         |
| P2            | 6.00               | 6      | 0.25 | +1                        | +         |
| P3            | 5.92               | 6      | 0    | +2                        | +         |
| P4            | 4.50               | 5      | 1    | +1                        | +         |
| P5            | 4.58               | 5      | 0.25 | +3                        | +         |
| P6            | 6.42               | 7      | 1    | +2                        | +         |
| P7            | 5.00               | 5      | 0.25 | +3                        | +         |
| P8            | 1.58               | 1      | 0.25 | −2                        | −         |
| P9            | 5.58               | 6      | 1    | +2                        | +         |
| P10           | 6.25               | 6      | 0.25 | +2                        | +         |
| P11           | 5.75               | 6      | 1    | +1                        | +         |
| P12           | 3.08               | 3      | 0.25 | −3                        | −         |
| P13           | 5                  | 5      | 0    | +3                        | +         |
| P14           | 6.58               | 7      | 1    | +2                        | +         |

Green ones reflects the ones reached consensus. Orange ones are the removed once regarding delphi process and the blue one is the added through delphi process.

As shown in Table 5, the Delphi process resulted in a refined behavioral framework by validating operationally relevant green behaviors through expert consensus. The finalized behavioral set was subsequently transferred without modification to the IT2F-AHP stage, ensuring methodological consistency between the qualitative consensus-building process and the quantitative prioritization process.

#### 4.4. Delphi Findings

The results of the Delphi approach, as shown in Table 5, provide significant insights into the Employee Green Behavior (EGB) practices deemed most essential by shipping professionals for attaining sustainable maritime operations. Of the fourteen practices assessed, “Adhering to Ballast Water Management Regulations” (P14) obtained the highest mean score ( $\bar{x} = 6.58$ ) and a median of 7, achieving consensus in the second round. This robust consensus underscores the practice’s ecological imperative and regulatory significance. Unlike the behaviors initially identified through the literature review, P14 (Adhering to Ballast Water Management Regulations) emerged during the Delphi process based on expert recommendations. The panel emphasized that ballast water management has become an essential operational responsibility of officer-class seafarers due to the implementation of the IMO Ballast Water Management Convention and its significant contribution to preventing marine biological pollution. Therefore, P14 was incorporated into the final behavioral framework prior to the IT2F-AHP analysis.

This outcome highlights the crucial role of officer-class seafarers in mitigating marine biodiversity loss through appropriate ballast water discharge within the framework of the IMO’s Ballast Water Management Convention and the wider environmental governance context. The incorporation of this behavior, suggested by experts in the qualitative content analysis, further substantiates the integrative efficacy of the Delphi method in identifying genuine operational goals that may be inadequately reflected in literature-based frameworks.

*Resource Efficiency* (P6) and *Environmental Awareness* (P10) were also significant, both achieving a score over 6. These actions clearly correspond with the decarbonization objectives outlined in the IMO Initial GHG Strategy (IMO, 2018 [95]) and the European Union's "Fit for 55" [29] legal framework. The priority of these practices by experts indicates an acknowledgment that sustainable shipping starts with optimizing output from finite resources and fostering cognitive engagement with environmental concerns. *Water Conservation* (P3), *Waste Reduction* (P2), and *Encouraging Others* (P11) received substantial agreement, as indicated by low interquartile ranges reflecting close alignment of expert evaluations. These behaviors represent low-tech, high-impact tactics that police can employ with immediate effect. The uniformity of these responses indicates a shared conviction that significant environmentally friendly actions do not necessarily necessitate systemic changes; instead, they rely on individual self-discipline and knowledge, particularly among officers responsible for implementing daily shipboard protocols.

*Energy Conservation* (P1) was assessed as pertinent (median = 5, IQR = 0) but garnered a lower mean score ( $\bar{x} = 5.00$ ), suggesting potential perceived constraints on officers' capacity to impact shipboard energy systems. This may indicate limitations arising from the design of propulsion and auxiliary systems, which frequently lie outside the direct control of officers. *Sustainable Purchasing* (P9) was deemed significant (median = 6); however, had a wider interquartile range, potentially attributable to the centralized structure of maritime procurement. These findings underscore a persistent topic in the Delphi study: whereas officers demonstrate a willingness to endorse environmental objectives, structural and institutional impediments persistently influence the practicability of specific actions.

Three practices, *Green Crafting* (P5), *Paperless Practices* (P7), and *Environmental Mentorship* (P13), were incorporated only after the third Delphi round, indicating early skepticism regarding their practical feasibility. Their eventual acceptance demonstrates a changing perspective among marine professionals, who are progressively receptive to embracing adaptable and proactive strategies for sustainability. These behaviors illustrate the dynamic evolution of green capabilities, wherein innovation, digitization, and peer learning are redefining conventional marine jobs. They also stress that environmentally friendly practices should go beyond mere compliance and routine, cultivating a corporate culture that prioritizes experimentation and ongoing enhancement.

*Sustainable Commuting* (P8) and *Participation in Green Initiatives* (P12) were, conversely, omitted. This omission underscores the importance of contextual relevance in behavioral frameworks: commuting is inconsequential in the maritime setting, whereas involvement in organizational efforts may exceed the scope of ship commanders' duties. The intentional omission of certain activities signifies a sophisticated, experience-based enhancement of the green behavior inventory, guaranteeing that all included items had both theoretical significance and practical applicability.

The Delphi findings constitute a comprehensive and contextually relevant prioritization of sustainable practices within the maritime sector. The chosen approaches demonstrate a balance of ecological effect, practicality, and compliance with international regulatory standards. The elevation of ballast water compliance to the apex of the behavioral ladder is notably symbolic, indicating a convergence between frontline operational conduct and global environmental governance. By integrating these verified techniques into seafarer training, performance evaluation, and aboard culture, maritime enterprises can more effectively connect their internal human systems with the external requirements of sustainable shipping. This connection is crucial for achieving the ambitious decarbonization [28] and environmental preservation objectives established by both the IMO and the European Union as the industry progresses towards net-zero emissions by 2050 [2].

#### 4.5. Interval Type-2 Fuzzy AHP

Van Laarhoven and Pedrycz (1983) [141] are widely acknowledged as the pioneers who first introduced fuzzy comparative judgments in decision-making, representing preferences using triangular fuzzy numbers. Their contribution laid the groundwork for subsequent developments, including Chang's (1996) [142] fuzzy synthetic extent method and later enhancements to fuzzy decision frameworks. Although the Analytic Hierarchy Process (AHP) has been extensively utilized to structure complex decision problems by capturing expert opinions, conventional AHP relies on precise numerical inputs and thus falls short of accurately representing the inherent vagueness and cognitive ambiguity associated with human decision processes. To address this limitation, the Fuzzy Analytic Hierarchy Process (F-AHP) was proposed as an extension of AHP to handle perception-based, linguistically expressed, and context-dependent judgments [143,144]. Through the use of fuzzy linguistic scales, decision-makers can articulate preferences more realistically, and these fuzzy evaluations are then aggregated to obtain meaningful perceptual priorities [145–147].

F-AHP has been recognized as an effective methodological tool for multi-criteria sustainability evaluations due to its capacity to address ambiguity in human judgment [112,116]. In sustainability-oriented organizational and operational contexts, it has demonstrated significant advantages over traditional AHP by integrating uncertainty more explicitly and permitting a systematic evaluation of multidimensional criteria such as waste reduction, resource efficiency, and green organizational practices [148,149]. However, even Type-1 fuzzy approaches assume a relatively stable membership function and therefore accommodate only limited levels of uncertainty.

In the present study, the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP) was adopted as the most appropriate and robust methodological approach to evaluate and prioritize Employee Green Behavior (EGB) practices among officer-class seafarers. Unlike classical AHP, which requires exact pairwise judgments, and Type-1 Fuzzy AHP, which captures only first-level fuzziness, IT2F-AHP enables the modeling of higher-order uncertainty through interval-valued fuzzy membership functions [113]. This is particularly important in the maritime domain, where expert judgments are shaped by dynamic operational environments, time pressure, safety-critical decisions, heterogeneous vessel types, regulatory variability, and linguistically articulated expertise. Accordingly, IT2F-AHP allows expert opinions to be represented not as fixed values but as bounded intervals, thereby more accurately reflecting cognitive imprecision, subjective interpretation, and epistemic uncertainty [111,114].

To further justify the selection of IT2F-AHP, Table 6 compares the methodological characteristics of Classical AHP, Type-1 Fuzzy AHP, and IT2F-AHP with respect to their capability to handle uncertainty, expert hesitation, and linguistic ambiguity.

**Table 6.** Methodological justification for selecting the IT2F-AHP approach: Comparison of Classical AHP, Type-1 Fuzzy AHP, and IT2F-AHP.

| Method                               | Handling Uncertainty | Expert Hesitation | Linguistic Ambiguity | Main Limitation                                                                                                          | Supporting Literature |
|--------------------------------------|----------------------|-------------------|----------------------|--------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Classical AHP                        | Low                  | No                | Limited              | Requires precise pairwise comparisons and deterministic judgments                                                        | [111,112]             |
| Type-1 Fuzzy AHP                     | Moderate             | Partially         | Good                 | Represents uncertainty using fixed membership functions but cannot fully capture higher-order uncertainty                | [111,113]             |
| Interval Type-2 Fuzzy AHP (IT2F-AHP) | High                 | Yes               | Excellent            | Higher computational complexity but provides a more robust representation of uncertainty and expert judgment variability | [113–117]             |

As summarized in Table 6, Classical AHP assumes precise pairwise comparisons and therefore provides limited capability for representing uncertainty inherent in expert-based evaluations. Type-1 Fuzzy AHP partially addresses this limitation by incorporating fuzzy linguistic judgments; however, it still relies on fixed membership functions that cannot fully represent higher-order uncertainty associated with heterogeneous expert opinions. In contrast, IT2F-AHP introduces an additional degree of freedom through interval type-2 fuzzy sets, enabling a more effective representation of linguistic ambiguity, expert hesitation, and variability in pairwise evaluations. Considering that the present study relies on expert judgments obtained from maritime professionals with diverse operational backgrounds, IT2F-AHP was considered the most appropriate method for deriving robust and reliable priority weights.

Moreover, IT2F-AHP has been increasingly employed in complex maritime decision-making problems due to its methodological robustness and suitability for uncertainty-driven operational systems. Previous studies have demonstrated its effectiveness in maritime safety management, sustainability assessments, and decision environments requiring nuanced prioritization under ambiguity [115,117,150,151]. In line with this literature, the adoption of IT2F-AHP in the present research ensured not only technical rigor but also operational realism. By integrating interval type-2 fuzziness with hierarchical prioritization, the method captured the linguistic variability and expert heterogeneity inherent in assessing shipboard environmental behaviors, thereby yielding results that are both analytically reliable and practically meaningful. This methodological choice strengthens the credibility of the final prioritization outcomes, ensuring that the identified EGB practices reflect realistic behavioral priorities within sustainability-driven maritime operations.

#### 4.6. Data Collection for IT2F-AHP

The purposive sampling strategy employed in the Delphi phase was also adopted for the IT2F-AHP data collection, reflecting its suitability for expert-driven decision-making studies. Purposive sampling is widely endorsed in fuzzy and expert-based multi-criteria decision-making research because the objective is not random representativeness but the inclusion of highly knowledgeable participants capable of providing informed, experience-based, and contextually grounded evaluations. Accordingly, participants for the IT2F-AHP phase were selected among qualified ship officers and shore-based maritime personnel managers who demonstrated (i) substantial professional experience in ship operations or human resource management, (ii) familiarity with environmental performance and sustainability-oriented practices, and (iii) active involvement in decision-making or supervisory responsibilities within their organizations. Participation was voluntary, and only those who confirmed their willingness and availability to engage meaningfully in the evaluation process were included (see Table 7). This approach ensured methodological rigor by prioritizing expert competence over numerical sample size, aligning with best practices in expert-judgment research.

Table 7 provides a comprehensive profile of the 15 experts who participated in the IT2F-AHP phase, illustrating substantial diversity in demographic and professional attributes. The expert panel comprised both shore-based personnel managers and senior officer-class seafarers, including masters, chief officers, and engineering officers, representing key operational roles across different ship types, particularly bulk carriers and tankers. Their professional experience ranged from 3 to 22 years, ensuring a balanced composition of senior expertise and emerging professional insight. Although the panel predominantly consisted of male experts (11), the inclusion of four female officers, particularly in engineering roles, contributed to gender diversity. Academically, nine experts held bachelor's degrees, three possessed master's degrees, and three held doctoral qualifications, demonstrating robust academic grounding alongside operational competence.

The diversity in rank, ship type exposure, gender composition, and educational attainment strengthens the contextual validity of the IT2F-AHP findings and enhances the interpretive depth of the prioritization outcomes.

**Table 7.** Profile of the F-AHP respondents.

| Expert No | Ship Type                    | Position                    | Years of Experience in HR/Logistics | Gender | Education         |
|-----------|------------------------------|-----------------------------|-------------------------------------|--------|-------------------|
| 1         | Bulk Carrier                 | Personnel Manager           | 15                                  | Male   | Master's Degree   |
| 2         | Tugboat                      | Ocean-Going Second Engineer | 10                                  | Female | Bachelor's Degree |
| 3         | Drillship                    | Ocean-Going Master          | 15                                  | Male   | PhD               |
| 4         | Tanker                       | Ocean-Going Second Engineer | 6                                   | Male   | PhD               |
| 5         | Bulk Carrier, Container Ship | Ocean-Going Watch Officer   | 3                                   | Male   | Bachelor's Degree |
| 6         | Bulk Carrier                 | Ocean-Going Second Engineer | 5                                   | Male   | PhD               |
| 7         | Bulk Carrier                 | Ocean-Going Watch Engineer  | 12                                  | Male   | PhD               |
| 8         | Bulk Carrier                 | Ocean-Going Chief Officer   | 15                                  | Male   | Bachelor's Degree |
| 9         | Chemical Tanker              | Personnel Manager           | 22                                  | Male   | Bachelor's Degree |
| 10        | Tanker                       | Personnel Manager           | 17                                  | Male   | Master's Degree   |
| 11        | Tanker                       | Ocean-Going Master          | 10                                  | Male   | Master's Degree   |
| 12        | Tanker                       | Ocean-Going Chief Officer   | 14                                  | Female | Bachelor's Degree |
| 13        | Container                    | Ocean-Going Watch Officer   | 3                                   | Female | Bachelor's Degree |
| 14        | Ro-ro                        | Ocean-Going Second Engineer | 5                                   | Female | Bachelor's Degree |
| 15        | Container                    | Ocean-Going Watch Engineer  | 3                                   | Male   | Bachelor's Degree |

To evaluate the relative importance of the 12 validated Employee Green Behavior (EGB) practices, a structured questionnaire was administered. The EGB practices were systematically categorized under environmental, economic, and social sustainability dimensions based on an extensive review of the literature, while their operational relevance to maritime contexts had been previously verified through the Delphi phase. Participants were asked to perform pairwise comparisons of the EGB practices within the sustainability hierarchy, evaluating the extent to which each behavior contributed to the enhancement of environmental, economic, or social sustainability in shipping operations. The survey design emphasized the elicitation of individual expert judgments rather than forcing consensus, thereby preserving the uniqueness of experiential insight and avoiding conformity bias. A standardized linguistic pairwise comparison scale (see Table 7) was used to enable clear, structured articulation of expert perceptions. This approach facilitated the extraction of nuanced, perception-based evaluations and ensured methodological rigor and reliability in the IT2F-AHP prioritization process.

#### 4.7. Interval Type-2 F-AHP Model

This research utilized the Fuzzy Analytic Hierarchy Process (F-AHP) using Interval Type-2 fuzzy sets to evaluate and rank Employee Green Behavior (EGB) practices pertinent to ship officers. The Analytic Hierarchy Process (AHP), conceived by Saaty in 1980 [152], is a multi-criteria decision-making (MCDM) framework that organizes problems hierarchically, delineating objectives, criteria, and alternatives. AHP often employs precise numerical assessments; however, actual decision-making frequently encompasses uncertainty and subjectivity. Fuzzy logic is incorporated into the process to improve the accuracy of expert assessments. This study employs Interval Type-2 fuzzy numbers, which include a spectrum of potential values instead of fixed points, thereby more effectively encapsulating the uncertainty in expert assessments [153]. The methodology employs systematic procedures to guarantee consistency, reduce expert bias, and improve the reliability of pairwise comparisons [154]. Fuzzy sets enhance decision-making by improving precision. Furthermore, the introduction of IT2Fs provides a superior solution compared to IT1Fs due to the variable membership features of IT2Fs [111]. IT2F-AHP has been utilized in numerous issues since its introduction in the literature [116,117]. The linguistic variables of IT2Fs are displayed in Table 8.

**Table 8.** Linguistic scale of the research.

| Linguistic Variables |                   | Interval Type-2 Fuzzy Sets                            |
|----------------------|-------------------|-------------------------------------------------------|
| AS                   | Absolutely Strong | $((7, 8.9, 9; 1, 1), (7.2, 8.2, 8.8, 9.0; 0.8, 0.8))$ |
| VS                   | Very Strong       | $((5, 6.8, 9; 1, 1), (5.2, 6.2, 7.8, 8.8; 0.8, 0.8))$ |
| FS                   | Fairly Strong     | $((3, 4.6, 7; 1, 1), (3.2, 4.2, 5.8, 6.8; 0.8, 0.8))$ |
| SS                   | Slightly Strong   | $((1, 2.4, 5; 1, 1), (1.2, 2.2, 3.8, 4.8; 0.8, 0.8))$ |
| E                    | Exactly Equally   | $((1, 1, 1, 1; 1, 1), (1, 1, 1, 1; 1, 1))$            |

If parameter  $i$  has one of the linguistic variables appointed to it Reciprocals of the above when matched with parameter  $j$ , then  $j$  has the mutual value when matched with  $i$ . Source: [111].

The IT2F-AHP method is presented step by step as follows [111]:

**Step 1:** The problem is defined with a goal. The hierarchical structure is built up along with its main factors and sub-factors at all levels.

**Step 2:** Build the IT2FSs pairwise comparison matrix as  $\tilde{A}$  and the average decision matrix  $\bar{A}$ . In Equations (1) and (2), the pairwise comparison matrix is presented as below.

$$\tilde{A}_k = (\tilde{a}_{ij}^k)_{n \times n} = \begin{bmatrix} 1 & \tilde{a}_{12}^k & \dots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & 1 & \dots & \tilde{a}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1}^k & \tilde{a}_{n2}^k & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12}^k & \dots & \tilde{a}_{1n}^k \\ 1/\tilde{a}_{12}^k & 1 & \dots & \tilde{a}_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n}^k & 1/\tilde{a}_{2n}^k & \dots & 1 \end{bmatrix} \quad (1)$$

$$\bar{A} = (\bar{a}_{ij})_{n \times n}, \quad (2)$$

where

$$1/\tilde{a} = \left( \left( \frac{1}{a_{14}^U}, \frac{1}{a_{13}^U}, \frac{1}{a_{12}^U}, \frac{1}{a_{11}^U}, H_1(a_{12}^U), H_2(a_{13}^U) \right), \right. \\ \left. \left( \frac{1}{a_{24}^L}, \frac{1}{a_{23}^L}, \frac{1}{a_{22}^L}, \frac{1}{a_{21}^L}, H_1(a_{22}^L), H_2(a_{23}^L) \right) \right).$$

The geometric mean of  $k$  IT2FSs is evaluated for  $k$ th decision makers. In Table 8, the linguistic variables are represented for evaluation. The decision makers' decisions in the pairwise comparison matrices are aggregated by means of the geometric mean method in Equation (3). The IT2FSs linguistic variables are presented in Table 8.

$$\tilde{a}_{ij} = \left[ \tilde{a}_{ij}^1 \otimes \tilde{a}_{ij}^2 \otimes \dots \otimes \tilde{a}_{ij}^k \right]^{1/k} = \sqrt[k]{\tilde{a}_{ij}^1 \otimes \tilde{a}_{ij}^2 \otimes \dots \otimes \tilde{a}_{ij}^k} \quad (3)$$

where

$$\sqrt[n]{\tilde{a}_{ij}} = \left( \left( \sqrt[n]{a_{ij1}^U}, \sqrt[n]{a_{ij2}^U}, \sqrt[n]{a_{ij3}^U}, \sqrt[n]{a_{ij4}^U}; H_1^U(\tilde{a}_{ij}), H_2^U(\tilde{a}_{ij}) \right), \right. \\ \left. \left( \sqrt[n]{a_{ij1}^L}, \sqrt[n]{a_{ij2}^L}, \sqrt[n]{a_{ij3}^L}, \sqrt[n]{a_{ij4}^L}; H_1^L(\tilde{a}_{ij}), H_2^L(\tilde{a}_{ij}) \right) \right).$$

**Step 3:** Analyze the consistency of the IT2FSs pairwise comparison matrices. When con-

sidering  $A = [a_{ij}]$  as a positive reciprocal matrix,  $\tilde{A} = [\tilde{a}_{ij}]$  is supposed to be a positive reciprocal matrix. As a result,  $A = [a_{ij}]$  is consistent, so  $\tilde{A} = [\tilde{a}_{ij}]$  is also consistent.

**Step 4:**  $\tilde{r}_i$  is computed by means of Equation (4) based on the IT2FSs weight's geometric mean of each row of  $\tilde{A} = [\tilde{a}_{ij}]$  for applying each criterion as below.

$$\tilde{r}_i = \left[ \tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \dots \otimes \tilde{a}_{in} \right]^{1/n} \quad (4)$$

where,

$$\sqrt[n]{\tilde{a}_{ij}} = \left( \left( \sqrt[n]{a_{ij1}^U}, \sqrt[n]{a_{ij2}^U}, \sqrt[n]{a_{ij3}^U}, \sqrt[n]{a_{ij4}^U}; H_1^U(\tilde{a}_{ij}), H_2^U(\tilde{a}_{ij}) \right), \right. \\ \left. \left( \sqrt[n]{a_{ij1}^L}, \sqrt[n]{a_{ij2}^L}, \sqrt[n]{a_{ij3}^L}, \sqrt[n]{a_{ij4}^L}; H_1^L(\tilde{a}_{ij}), H_2^L(\tilde{a}_{ij}) \right) \right).$$

**Step 5:** The IT2FSs weight  $i^{th}$  criterion is computed by applying Equation (5), below.

$$\tilde{w}_i = \tilde{r}_i \otimes \left[ \tilde{r}_1 \oplus \dots \oplus \tilde{r}_i \oplus \dots \oplus \tilde{r}_n \right]^{-1} \quad (5)$$

where,

$$\frac{\tilde{a}}{\tilde{b}} = \left( \left( \frac{a_1^U}{b_4^U}, \frac{a_2^U}{b_3^U}, \frac{a_3^U}{b_2^U}, \frac{a_4^U}{b_1^U}, \min(H_1^U(\tilde{a}), H_1^U(\tilde{b})), \min(H_2^U(\tilde{a}), H_2^U(\tilde{b})) \right), \right. \\ \left. \left( \frac{a_1^L}{b_4^L}, \frac{a_2^L}{b_3^L}, \frac{a_3^L}{b_2^L}, \frac{a_4^L}{b_1^L}, \min(H_1^L(\tilde{a}), H_1^L(\tilde{b})), \min(H_2^L(\tilde{a}), H_2^L(\tilde{b})) \right) \right).$$

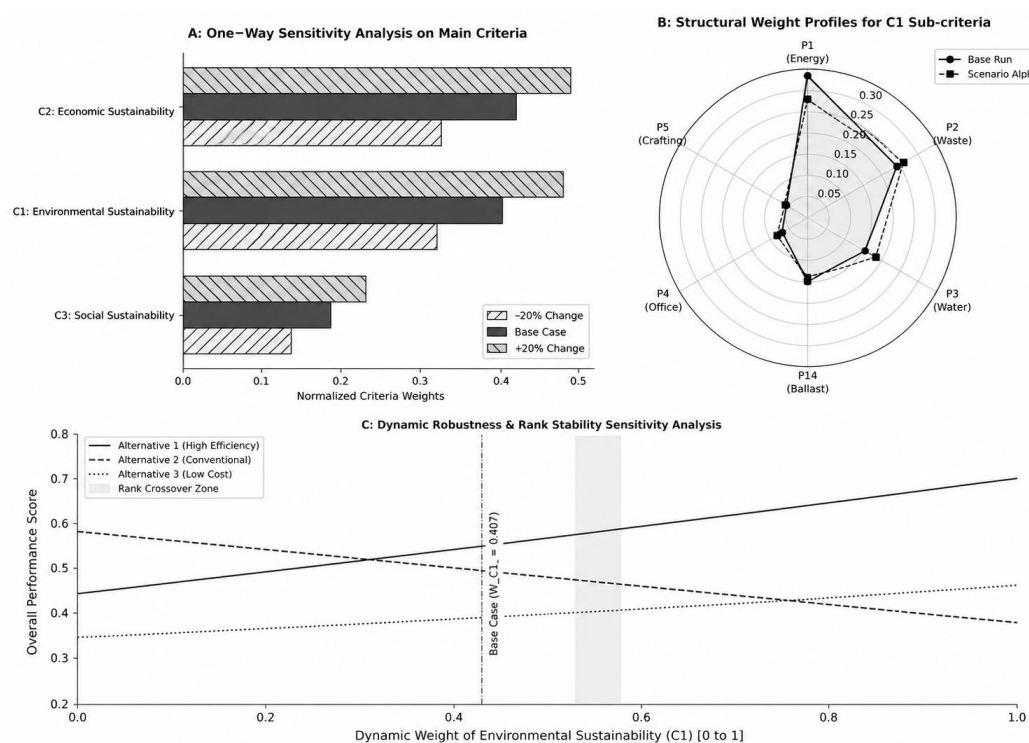
**Step 6:** The ranking of the obtained results through defuzzification is consistent with the expected order of trapezoidal IT2FSs ( $D_{TraT}$ ) as in Equation (6).

$$D_{TraT} = \frac{\left[ \frac{(u_U - l_U) + (\beta_U m_{1U} - l_U) + (\alpha_U m_{2U} - l_U)}{4} + l_U \right] + \left[ \frac{(u_L - l_L) + (\beta_L m_{1L} - l_L) + (\alpha_L m_{2L} - l_L)}{4} + l_L \right]}{2} \quad (6)$$

where  $a$  and  $\beta$  are the maximum membership degrees of the lower membership function of the considered IT2FSs.  $u_U$  is the largest possible value,  $l_U$  is the least possible value and,  $m_{1U}$  and  $m_{2U}$  are the second and third parameters in the upper membership function. Also,  $u_L$  is the largest possible value,  $l_L$  is the least possible value and,  $m_{1L}$  and  $m_{2L}$  are the second and third parameters in the lower membership function.

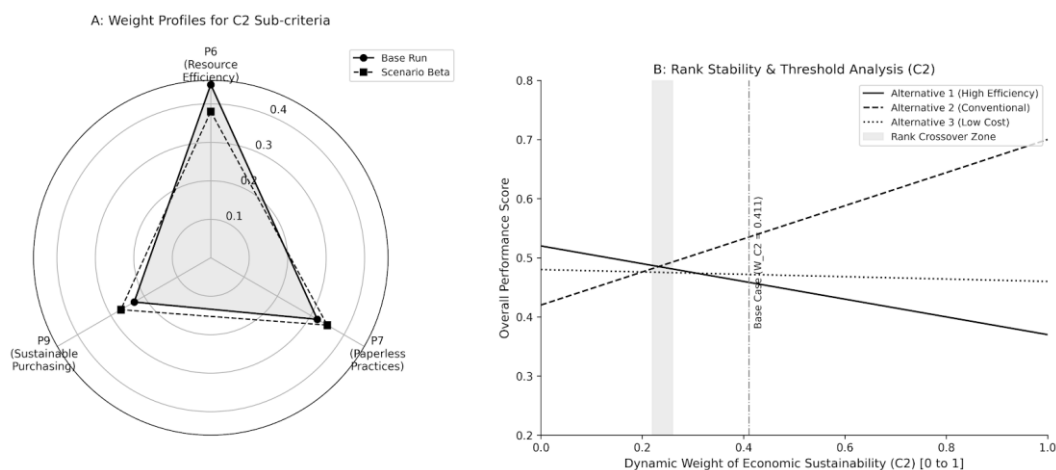
To ensure the reliability of the pairwise comparisons, consistency ratios (CRs) were calculated for all comparison matrices following Saaty's consistency criterion [152]. The CR values were found to be 0.0385 for the main criteria matrix, 0.0413 for the Environmental Sustainability matrix (C1), 0.0358 for the Economic Sustainability matrix (C2), and 0.0296 for the Social Sustainability matrix (C3). Since all CR values were below the recommended threshold of 0.10, the consistency of the expert judgments was considered satisfactory, confirming the reliability of the derived priority weights.

To evaluate the robustness of the proposed IT2F-AHP model, a one-way sensitivity analysis was performed by systematically varying the weights of the three main sustainability dimensions (Environmental, Economic, and Social Sustainability). In addition, structural weight profile analyses were conducted for the sub-criteria within each main criterion to examine the influence of alternative weighting scenarios on the resulting priority rankings. The analysis further investigated potential rank crossover points and threshold values to determine whether the obtained rankings remained stable under varying decision conditions (see Figures 3–5).

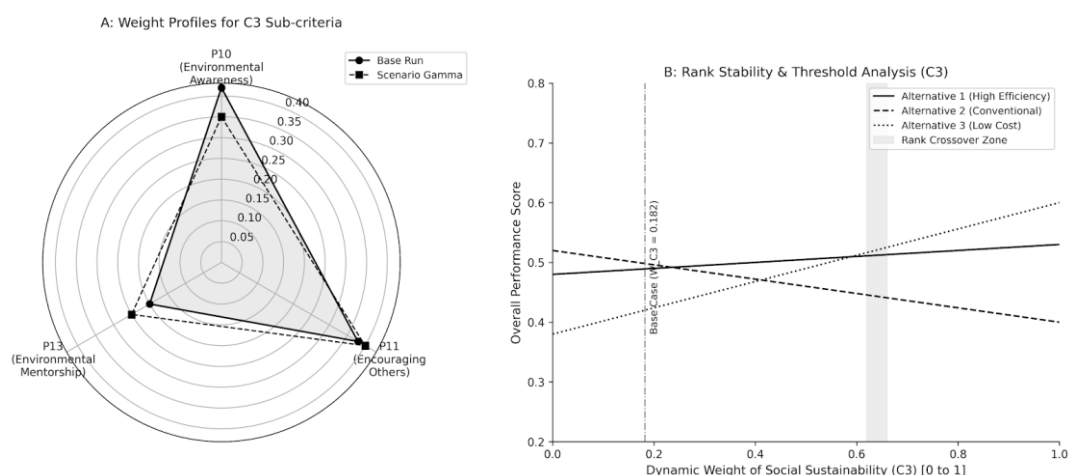


**Figure 3.** One-Way Sensitivity Analysis of Main Categories, Structural Weight Profiles, and Rank Stability Analysis for Environmental Sustainability (C1). Sensitivity analysis results for the Environmental Sustainability criterion (C1): (A) one-way sensitivity analysis of the main criteria under  $\pm 20\%$

weight variations, (B) structural weight profiles of the C1 sub-criteria under the baseline and alternative scenarios, and (C) dynamic robustness and rank stability analysis illustrating the effects of varying the C1 weights on the overall performance scores and potential rank crossover regions. Note: The light grey shaded area indicates the rank crossover zone, where changes in criterion weights may lead to changes in the relative ranking of alternatives.



**Figure 4.** Structural Weight Profiles and Rank Stability Analysis for Economic Sustainability (C2). Figure 4. Sensitivity analysis results for the Economic Sustainability criterion (C2): (A) structural weight profiles of the C2 sub-criteria under the baseline and alternative weighting scenarios, and (B) rank stability and threshold analysis illustrating the effects of varying the weight of Economic Sustainability (C2) on the overall performance scores and potential rank crossover regions. Note: The light grey shaded area represents the rank crossover zone, indicating the weight interval in which rank changes may occur.



**Figure 5.** Structural Weight Profiles and Rank Stability Analysis for Social Sustainability (C3). Figure 5. Sensitivity analysis results for the Social Sustainability criterion (C3): (A) structural weight profiles of the C3 sub-criteria under the baseline and alternative weighting scenarios, and (B) rank stability and threshold analysis illustrating the effects of varying the weight of Social Sustainability (C3) on the overall performance scores and potential rank crossover regions. Note: The light grey shaded area represents the rank crossover zone, indicating the weight interval in which rank changes may occur.

The sensitivity analysis demonstrated that the obtained rankings remained generally stable under moderate changes in the criterion weights. Although alternative weighting scenarios resulted in slight variations in normalized scores, the overall prioritization

structure exhibited high robustness. Rank reversals occurred only beyond specific threshold regions, while no substantial rank reversal was observed around the baseline weighting configuration. These findings confirm that the proposed IT2F-AHP model provides reliable and robust prioritization results that are not unduly influenced by moderate variations in expert judgments.

To enhance methodological transparency while maintaining the readability of the manuscript, the complete linguistic pairwise comparison matrices, aggregated IT2F decision matrices, consistency ratio (CR) values, normalized weights, and detailed weight derivation results are provided in the Supplementary Materials (Supplementary Materials), thereby ensuring the transparency and reproducibility of the IT2F-AHP analysis.

#### 4.8. Findings of Interval Type-2 F-AHP

Table 9 presents the interval type-2 fuzzy weights, normalized values, and final rankings of the three main sustainability dimensions, namely Environmental (C1), Economic (C2), and Social (C3), in the context of officer-class seafarers' green behavior practices. The obtained hierarchy signifies a pragmatic prioritization structure that mirrors both operational realities and strategic preferences within the maritime sector.

**Table 9.** Interval type-2 fuzzy weights, normalized values, and rankings of main categories.

| Category       | IT2 Fuzzy Weights                                                            | Weight | Normalized | Rank |
|----------------|------------------------------------------------------------------------------|--------|------------|------|
| C <sub>1</sub> | ((0.268, 0.327, 0.506, 0.733; 1, 1), (0.266, 0.343, 0.483, 0.612; 0.8, 0.8)) | 0.422  | 0.407      | 2    |
| C <sub>2</sub> | ((0.163, 0.351, 0.560, 0.634; 1, 1), (0.282, 0.370, 0.531, 0.691; 0.8, 0.8)) | 0.425  | 0.411      | 1    |
| C <sub>3</sub> | ((0.096, 0.121, 0.185, 0.533; 1, 1), (0.103, 0.127, 0.176, 0.230; 0.8, 0.8)) | 0.189  | 0.182      | 3    |

The Economic dimension (C2) emerged as the most influential category, achieving the highest normalized weight (0.411). This finding demonstrates that, within the decision environment of maritime professionals, economic considerations constitute the primary driver of sustainability-related behavioral decisions. In an industry characterized by fuel-intensive operations, volatile market conditions, and demanding cost-efficiency expectations, economic gains derived from sustainable practices such as fuel savings, reduced maintenance costs, and optimized resource utilization are perceived as the most immediate and tangible outcomes. Accordingly, sustainability is not conceptualized merely as an environmental ideal but as a financially rational and performance-enhancing imperative deeply integrated into operational and strategic decision-making.

Closely following, the Environmental dimension (C1) holds a normalized value of 0.407, indicating almost parallel importance to economic considerations. Although slightly secondary, the very narrow difference between C1 and C2 reveals that environmental stewardship has gained substantial strategic prominence in modern shipping. This reflects a structural transition within the industry, where environmental objectives are no longer viewed as competing with financial imperatives but rather as reinforcing cost efficiency, global reputation, and regulatory compliance. The convergence of environmental and economic significance suggests the emergence of a sustainability paradigm in which ecological responsibility, operational performance, and corporate competitiveness are mutually reinforcing.

The Social dimension (C3) ranks third with a normalized score of 0.182. Despite its comparatively lower weight, its inclusion and measurable relevance indicate that socially oriented sustainability components such as awareness, engagement, and mentoring remain integral to the sustainability architecture. However, their lower prioritization suggests that maritime decision-makers currently emphasize measurable, performance-related, and regulation-driven behaviors over culture-building and softer social enablers.

This reflects a prevailing operational mindset where results perceived as directly quantifiable and outcome-oriented are prioritized.

Table 10 synthesizes the final normalized weights of all EGB practices, structured within their respective sustainability dimensions. The dominance of the Economic dimension is further substantiated by the leading position of P6–Resource Efficiency (0.270), which ranks first among all behavioral practices. This demonstrates that behaviors contributing to optimized resource usage, fuel efficiency, and operational productivity are considered the most valuable enablers of green shipping. In a sector where marginal efficiency improvements can translate into significant cost reductions and emission decreases, resource efficiency becomes a strategic rather than merely environmental objective.

Interestingly, the next two highest-ranked practices are environmentally driven: P1–Energy Conservation (0.136) and P2–Waste Reduction (0.100). Their strong prioritization reflects the growing recognition that energy-efficient operations and effective waste management are not only moral or regulatory necessities, but also operationally advantageous and economically beneficial. These practices also correspond with key regulatory developments such as MARPOL Annex V and EEXI requirements, further reinforcing their strategic importance by directly linking environmental responsibility with compliance and the reduction of reputational risk.

The fourth-ranked criterion, P10–Environmental Awareness (0.096), belonging to the social sustainability dimension, highlights an acknowledgment that sustainable behavior is ultimately rooted in awareness, cognition, and individual value systems. Officers' capacity to understand environmental implications and internalize sustainability values plays a pivotal role in facilitating autonomous, proactive, and situationally appropriate eco-friendly decisions on board.

Mid-ranked practices such as P9–Sustainable Purchasing (0.095) and P3–Water Conservation (0.063) further emphasize the multidimensional nature of sustainability, extending beyond fuel and emissions toward responsible operational consumption. Although positioned below energy-related behaviors, they signify a progressive orientation toward comprehensive environmental stewardship.

Conversely, the relatively lower weights assigned to P5–Green Crafting (0.024), P4–Green Office Habits (0.028), and P11–Encouraging Others (0.030) suggest a limited emphasis on voluntary behavioral innovation, workplace cultural transformation, and peer influence mechanisms. This outcome may be attributed to structural characteristics of the maritime industry, such as highly formalized procedures, rigid hierarchies, and limited discretionary autonomy in shipboard environments, which can constrain the perceived relevance of discretionary and socially constructed sustainability behaviors.

Overall, the prioritization hierarchy reflects a pragmatic sustainability logic:

- First, behaviors yielding direct economic and operational performance gains;
- Second, environmentally compliant and regulation-aligned activities;
- Finally, social and cultural enablers of sustainability.

This layered structure implies that achieving a successful and enduring green transition in maritime operations requires a simultaneous focus on economically driven performance efficiency, environmentally constrained compliance, and gradual cultural transformation. The findings highlight that, for sustainability to move beyond being policy rhetoric, shipping companies must invest not only in technological solutions but also in behavioral capabilities, training systems, and supportive organizational cultures that empower officers to enact, sustain, and diffuse green behavior.

**Table 10.** Integrated weighting and ranking of criteria and sub-criteria for green behavior in the shipping context.

| Main Criteria                                                                        | Weight                                                                        | Normalized Rank | Sub-Criterion                                                                        | IT2F Weight                                                                   | Weight | Normalized Rank |    |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|--------|-----------------|----|
| C1<br>((0.268, 0.327, 0.506, 0.733;1, 1),<br>(0.266, 0.343, 0.483, 0.612;0.8, 0.8))  | 0.422                                                                         | 0.407           | P1<br>((0.105, 0.271, 0.458, 0.789;1, 1),<br>(0.211, 0.288, 0.433, 0.571;0.8, 0.8))  | ((0.028, 0.089, 0.232, 0.579;1, 1),<br>(0.056, 0.099, 0.209, 0.350;0.8, 0.8)) | 0.197  | 0.136           | 2  |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
|                                                                                      |                                                                               |                 | P2<br>((0.097, 0.174, 0.316, 0.629;1, 1),<br>(0.131, 0.186, 0.297, 0.410;0.8, 0.8))  | ((0.026, 0.057, 0.160, 0.461;1, 1),<br>(0.035, 0.064, 0.143, 0.251;0.8, 0.8)) | 0.145  | 0.100           | 3  |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
|                                                                                      |                                                                               |                 | P3<br>((0.050, 0.115, 0.212, 0.366;1, 1),<br>(0.088, 0.123, 0.198, 0.283;0.8, 0.8))  | ((0.013, 0.038, 0.107, 0.268;1, 1),<br>(0.023, 0.042, 0.096, 0.173;0.8, 0.8)) | 0.092  | 0.063           | 6  |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| P4<br>((0.035, 0.039, 0.067, 0.239;1, 1),<br>(0.032, 0.041, 0.063, 0.089;0.8, 0.8))  | ((0.009, 0.013, 0.034, 0.175;1, 1),<br>(0.008, 0.014, 0.030, 0.054;0.8, 0.8)) | 0.041           | 0.028                                                                                | 11                                                                            |        |                 |    |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| C2<br>((0.163, 0.351, 0.560, 0.634;1, 1),<br>(0.282, 0.370, 0.531, 0.691;0.8, 0.8))  | 0.425                                                                         | 0.411           | P5<br>((0.033, 0.033, 0.057, 0.195;1, 1),<br>(0.027, 0.035, 0.053, 0.076;0.8, 0.8))  | ((0.009, 0.011, 0.029, 0.143;1, 1),<br>(0.007, 0.012, 0.026, 0.046;0.8, 0.8)) | 0.034  | 0.024           | 12 |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
|                                                                                      |                                                                               |                 | P14<br>((0.083, 0.120, 0.218, 0.261;1, 1),<br>(0.092, 0.128, 0.204, 0.292;0.8, 0.8)) | ((0.022, 0.039, 0.110, 0.191;1, 1),<br>(0.025, 0.044, 0.099, 0.179;0.8, 0.8)) | 0.085  | 0.059           | 7  |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
|                                                                                      |                                                                               |                 | P6<br>((0.171, 0.574, 0.847, 1.714;1, 1),<br>(0.476, 0.601, 0.812, 0.994;0.8, 0.8))  | ((0.028, 0.202, 0.475, 1.086;1, 1),<br>(0.134, 0.222, 0.431, 0.687;0.8, 0.8)) | 0.392  | 0.270           | 1  |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| P7<br>((0.057, 0.080, 0.124, 0.482;1, 1),<br>(0.069, 0.084, 0.117, 0.157;0.8, 0.8))  | ((0.009, 0.028, 0.069, 0.305;1, 1),<br>(0.019, 0.031, 0.062, 0.108;0.8, 0.8)) | 0.077           | 0.053                                                                                | 8                                                                             |        |                 |    |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| P9<br>((0.111, 0.161, 0.255, 0.750;1, 1),<br>(0.134, 0.169, 0.242, 0.322;0.8, 0.8))  | ((0.018, 0.057, 0.143, 0.475;1, 1),<br>(0.038, 0.063, 0.129, 0.223;0.8, 0.8)) | 0.138           | 0.095                                                                                | 5                                                                             |        |                 |    |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| P10<br>((0.323, 0.436, 0.730, 0.945;1, 1),<br>(0.339, 0.461, 0.694, 0.905;0.8, 0.8)) | ((0.031, 0.053, 0.135, 0.503;1, 1),<br>(0.035, 0.059, 0.122, 0.208;0.8, 0.8)) | 0.139           | 0.096                                                                                | 4                                                                             |        |                 |    |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| C3<br>((0.096, 0.121, 0.185, 0.533;1, 1),<br>(0.103, 0.127, 0.176, 0.230;0.8, 0.8))  | 0.189                                                                         | 0.182           | P11<br>((0.105, 0.124, 0.216, 0.315;1, 1),<br>(0.100, 0.130, 0.203, 0.291;0.8, 0.8)) | ((0.010, 0.015, 0.040, 0.168;1, 1),<br>(0.010, 0.017, 0.036, 0.067;0.8, 0.8)) | 0.044  | 0.030           | 10 |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |
| P13<br>((0.162, 0.210, 0.352, 0.436;1, 1),<br>(0.168, 0.222, 0.333, 0.451;0.8, 0.8)) | ((0.028, 0.089, 0.232, 0.579;1, 1),<br>(0.056, 0.099, 0.209, 0.350;0.8, 0.8)) | 0.066           | 0.046                                                                                | 9                                                                             |        |                 |    |
|                                                                                      |                                                                               |                 |                                                                                      |                                                                               |        |                 |    |

## 5. Discussion

The findings of this study present a compelling synthesis of expert-informed consensus and robust computational decision modeling, offering substantive evidence regarding the prioritization of environmentally sustainable behaviors among officer-class seafarers. The Delphi results revealed strong agreement among maritime professionals concerning the necessity of operationally grounded and context-specific practices, such as resource

efficiency, waste reduction, and ballast water management, as essential levers for achieving sustainability at sea. These outcomes reflect earlier scholarly assertions emphasizing the pivotal role of officers as frontline implementers who convert environmental policies into actionable routines [8,9].

The subsequent IT2F-AHP analysis advanced this understanding by differentiating the relative strategic importance of these practices under conditions of uncertainty. While the Delphi method confirmed what matters, the IT2F-AHP method clarified what matters most, revealing that resource efficiency (P6) emerged as the highest priority, followed closely by energy conservation (P1) and waste reduction (P2). This result illustrates the growing alignment between economic rationality and environmental stewardship in maritime operations, supporting prior arguments that sustainability in shipping can and should serve both ecological and economic imperatives [24,31]. The dominance of economic sustainability (C2) reflects a pragmatic perspective: actions perceived as generating measurable financial gains and operational performance improvements receive greater emphasis, echoing wider industry trends documented by UNCTAD (2023) [28] and IMO (2023) [2].

It is important to distinguish “Adhering to Ballast Water Management Regulations” (P14) from several other prioritized green behaviors in terms of its conceptual nature. Unlike behaviors such as energy conservation or resource efficiency, ballast water management is fundamentally a mandatory environmental compliance requirement established under the IMO Ballast Water Management Convention. Nevertheless, its effective implementation relies heavily on the operational diligence, environmental responsibility, and day-to-day behavioral decisions of officer-class seafarers. Accordingly, P14 should not be interpreted as a purely voluntary Employee Green Behavior (EGB), but rather as a compliance-oriented environmental behavior whose successful execution depends on individual pro-environmental commitment. Therefore, the high priority assigned to this behavior reflects not only the importance of regulatory compliance but also the critical role of officers in translating mandatory environmental regulations into effective shipboard environmental practice.

Importantly, although environmental sustainability (C1) ranked slightly below economic sustainability, the marginal difference between their weights reveals a converging paradigm in which environmental and financial considerations are increasingly interdependent rather than antagonistic. This reinforces contemporary debates that position sustainability as a value-creating mechanism rather than a compliance burden. Conversely, the comparatively lower emphasis on social sustainability (C3) suggests that softer, culture-driven enablers, such as awareness, mentoring, and engagement, remain underprioritized despite being theoretically recognized as critical behavioral catalysts [71,96]. This divergence highlights an important tension within maritime sustainability: while technical and operational behaviors receive strategic focus, cultural and identity-based determinants are still developing.

Although the Social Sustainability dimension (C3) received the lowest overall priority weight, this finding should not be interpreted as indicating that social factors have a lower influence on sustainable shipboard operations. Rather, the IT2F-AHP results reflect the experts’ relative prioritization of the sustainability dimensions within the proposed decision framework. Employee Green Behavior literature suggests that leadership-oriented behaviors, such as encouraging others and environmental mentorship, contribute to organizational sustainability by promoting environmental awareness and strengthening collective pro-environmental behaviors among employees [9,26]. Within maritime settings, officer-class seafarers further reinforce this process by acting as operational leaders who translate sustainability policies into daily shipboard practices and influence the en-

vironmental behaviors of other crew members [5,101–106]. Consequently, leadership-oriented behaviors may exert an indirect but substantial influence by facilitating the adoption of higher-priority operational practices, particularly Energy Conservation (P1) and Resource Efficiency (P6), which emerged as the two highest-ranked behaviors in the IT2F-AHP analysis. Furthermore, compared with tangible environmental and economic practices, leadership, organizational culture, and other social factors are inherently more difficult to evaluate through pairwise comparison-based MCDM techniques because their effects often emerge indirectly through behavioral diffusion rather than immediate operational outcomes [27,30,31]. Therefore, the relatively lower weight assigned to the Social Sustainability dimension should be interpreted as a prioritization outcome within the IT2F-AHP framework rather than as evidence of a lower practical contribution to sustainable ship operation.

These findings are closely aligned with broader regulatory and corporate developments. The IMO's revised GHG strategy and the European Commission's regulatory frameworks increasingly emphasize behavioral efficiency, energy optimization, and reduction in environmental footprint as core compliance expectations. Corporate sustainability reports from leading maritime companies (e.g., Hapag-Lloyd, CMA CGM, and NYK Line) similarly underscore crew engagement, training, and onboard efficiency programs as critical performance pillars. Consistent with the World Maritime University's (2024) [15] identification of seafarer behavior as the "missing link" in maritime sustainability, the present study provides an empirically grounded prioritization framework that helps operationalize this missing component.

At the same time, the results reveal that certain sustainability practices widely acknowledged in land-based organizations, such as sustainable commuting or broad voluntary green participation programs, have limited direct applicability in maritime contexts. This supports calls for contextualized sustainability frameworks that recognize the distinctive structural, operational, and organizational features of shipboard environments [105]. Moreover, the relatively lower ranking of practices such as green crafting and peer encouragement points to institutional constraints stemming from hierarchical command structures, procedural rigidity, and restricted discretionary autonomy on board ships. Without organizational empowerment, leadership backing, and structured incentives, the behavioral potential of officers may remain only partially realized [5].

The prioritization results further demonstrate that the identified behaviors are operationally embedded within the daily responsibilities of officer-class seafarers. For instance, resource efficiency is reflected in voyage planning, machinery operation, and the optimal utilization of onboard resources, while energy conservation is achieved through fuel-efficient operational practices and effective auxiliary machinery management. Similarly, adherence to ballast water management regulations constitutes a critical operational responsibility governed by international maritime conventions and directly contributes to marine environmental protection. These findings confirm that the prioritized behaviors are not generic workplace environmental practices but ship-specific operational green behaviors that are inherently integrated into officers' daily decision-making processes and sustainability responsibilities onboard ships.

Overall, the dual-method strategy applied in this research successfully bridges the gap between strategic sustainability aspirations and human behavioral execution. Delphi ensured conceptual and contextual validity through evidence-based expert insight, while IT2F-AHP translated these insights into a precise and hierarchically robust prioritization structure. Together, they produce a scalable, flexible, and industry-relevant framework capable of guiding policymakers, shipping companies, and maritime educators in designing targeted interventions. The results highlight a layered sustainability pathway: first

strengthening economically rational efficiency behaviors, then reinforcing environmentally aligned operational practices, and progressively nurturing the social–cultural foundations that sustain long-term behavioral transformation in maritime operations.

## 6. Conclusions

This study proposes a methodologically rigorous and context-sensitive framework for prioritizing Employee Green Behavior (EGB) practices among officer-class seafarers, addressing the maritime industry's urgent need to operationalize sustainability at the behavioral level. By integrating Delphi with the Interval Type-2 Fuzzy Analytic Hierarchy Process (IT2F-AHP), the study effectively manages the inherent uncertainty and variability in expert judgments while validating a structured set of EGB practices aligned with the environmental, economic, and social pillars of sustainability. The findings demonstrate that practices such as resource efficiency, energy conservation, and waste reduction constitute not only feasible but also strategically critical behavioral priorities for advancing sustainable maritime operations and supporting global decarbonization initiatives.

An important theoretical contribution of this research is the contextual adaptation of Employee Green Behavior (EGB) to the maritime domain. Unlike previous EGB studies that predominantly focus on conventional organizational environments, this study demonstrates that environmentally responsible behaviors performed by officer-class seafarers are embedded within operational decision-making processes, environmental compliance requirements, and shipboard safety management systems. Accordingly, the identified behaviors extend the traditional EGB framework by incorporating operational responsibilities that are unique to maritime transportation and directly linked to sustainable ship operations [2,5,26,101–106].

Beyond its applied significance, the study contributes to sustainability theory by empirically illustrating how micro-level actions, particularly those undertaken by ship officers serve as decisive enablers for achieving macro-level environmental and economic outcomes. In doing so, the research helps close the conceptual gap between normative sustainability discourse and practical implementation, offering a behaviorally grounded taxonomy and a robust prioritization methodology that can inform decision-making in other safety-critical and highly regulated sectors as well.

The results hold substantial strategic value for maritime policymakers, fleet managers, and human resource practitioners seeking to embed sustainability into shipboard culture and operational systems. By identifying behaviors that are both influential and actionable, the study provides a foundation for designing targeted training programs, competency frameworks, performance assessment mechanisms, and incentive structures. These insights are particularly relevant in light of tightening international regulatory frameworks such as the IMO GHG Strategy and the European Union's Fit for 55 initiative, which increasingly demand behavioral alignment alongside technological advancement.

To facilitate the practical translation of the IT2F-AHP prioritization results into operational practice, Table 11 presents an action matrix that links each high-priority green behavior with corresponding training modules, onboard procedures, responsible actors, monitoring indicators, and expected sustainability outcomes. Rather than serving solely as a summary of the findings, the framework functions as a practical decision-support tool that can assist shipping companies, maritime education and training institutions, and regulatory authorities in integrating environmental behaviors into organizational policies, competency development, and sustainability management systems.

**Table 11.** Practical implementation framework for promoting prioritized green behaviors among officer-class seafarers.

| Prioritized Green Behavior     | Training Module                   | Onboard Procedure                                   | Responsible Actor         | Monitoring Indicator         | Expected Sustainability Outcome       |
|--------------------------------|-----------------------------------|-----------------------------------------------------|---------------------------|------------------------------|---------------------------------------|
| Energy conservation            | Energy-efficient ship operation   | Speed optimization, machinery efficiency monitoring | Master, Chief Engineer    | Fuel consumption, EEOI       | Reduced GHG emissions                 |
| Resource conservation          | Resource efficiency training      | Water and consumables management                    | Chief Officer             | Water/fuel consumption       | Reduced resource use                  |
| Ballast water management       | IMO BWM Convention training       | BWMS operation and compliance                       | Chief Officer             | PSC compliance, BWMS records | Prevention of marine invasive species |
| Environmental awareness        | Environmental management training | Toolbox meetings, environmental briefings           | Company and Ship Officers | Training participation       | Improved environmental culture        |
| Encouraging crew participation | Green leadership training         | Environmental suggestion systems                    | Master                    | Crew participation           | Stronger environmental engagement     |

Table 11 translates the prioritized green behaviors into a practical implementation framework for the maritime sector. Specifically, the highest-ranked behavior, energy conservation, can be operationalized through energy-efficient ship operation training, speed optimization practices, and machinery efficiency monitoring under the responsibility of Masters and Chief Engineers, with fuel consumption and the Energy Efficiency Operational Indicator (EEOI) serving as key performance indicators to support greenhouse gas emission reductions. Similarly, resource conservation can be promoted through resource efficiency training and onboard management of water and consumables, monitored through resource consumption metrics to improve operational efficiency. Ballast water management requires dedicated training on the IMO Ballast Water Management Convention and strict compliance with ballast water management system (BWMS) procedures, with Port State Control (PSC) compliance records providing measurable indicators of environmental performance. In addition, strengthening environmental awareness through environmental management training and regular toolbox meetings can foster a stronger environmental culture onboard, while encouraging crew participation through green leadership training and environmental suggestion systems can increase crew engagement and facilitate the long-term integration of sustainable practices into daily shipboard operations. Overall, the proposed action matrix operationalizes the IT2F-AHP prioritization results by providing a structured implementation pathway for shipping companies, maritime education and training institutions, and maritime regulators. Accordingly, the prioritization exercise is transformed from a ranking framework into an actionable decision-support tool capable of guiding sustainability-oriented behavioral interventions across the maritime sector.

It should be emphasized that the priority weights obtained through the Delphi–IT2F-AHP framework reflect the experts’ perceived importance of the identified green behaviors rather than their directly measured environmental impacts. Accordingly, higher priority weights should not be interpreted as evidence that a particular behavior produces greater reductions in greenhouse gas emissions, waste generation, water consumption, or environmental compliance risks. Instead, the prioritization results should be interpreted as reflecting expert consensus regarding the relative strategic importance of these behaviors for promoting sustainable shipboard operations rather than as empirical estimates of their environmental effectiveness. Future empirical studies may validate these findings

by examining the quantitative environmental outcomes associated with the implementation of the prioritized behaviors.

Nevertheless, certain limitations should be acknowledged. Although Delphi and IT2F-AHP enhanced methodological robustness, reliance on expert judgment, despite being systematically managed, inevitably introduces an element of subjectivity. Additionally, the exclusion of some commonly cited EGB practices due to contextual inapplicability (e.g., sustainable commuting) highlights the need for continual adaptation of sustainability frameworks to the lived realities of seafaring life. Future research may therefore extend this work through longitudinal analyses to observe behavioral change over time, expand expert participation across broader geographic regions to enhance generalizability, or conduct comparative studies across different vessel types and organizational contexts.

Although the present study does not include an independent empirical validation stage (e.g., application in a real shipping company or evaluation by a second expert panel), several procedures were implemented to enhance the credibility and robustness of the proposed framework. The Delphi process ensured iterative expert consensus, consistency ratios confirmed the reliability of pairwise comparisons, and comprehensive sensitivity analyses demonstrated that the prioritization results remained stable under alternative weighting scenarios. Nevertheless, future studies may further validate the proposed framework through real-world case applications, independent expert panels, or comparisons with observed environmental performance indicators.

Further inquiry may also investigate whether the prioritization of green behaviors changes under emerging autonomous and digitally supported ship operations, where the roles, responsibilities, and decision-making processes of officer-class seafarers are expected to evolve substantially. Examining how increasing levels of automation influence the relative importance and practical implementation of the identified green behaviors would provide valuable insights into the future of sustainable maritime operations. In addition, organizational enablers such as green leadership, supportive policy environments, and digitalization may be examined as moderating factors affecting the adoption and effectiveness of the prioritized green behaviors. Mixed-method designs combining observational data, onboard performance analytics, and advanced decision-support models could further enhance understanding of the long-term effectiveness and adaptability of these behaviors across different operational contexts.

Although the robustness of the proposed IT2F-AHP framework was evaluated through consistency analysis and comprehensive sensitivity analyses based on criterion-weight variations, all expert judgments were treated with equal importance throughout the Delphi and IT2F-AHP processes. Recent methodological studies have emphasized that assuming equal importance among experts may not always adequately capture differences in professional experience, domain expertise, or familiarity with the decision problem and that alternative expert-weighting strategies can provide additional insights into the robustness of MCDM results. In particular, previous studies have recommended comparing equal weighting, experience-based weighting, and familiarity-based weighting schemes to examine how different assumptions regarding expert importance influence prioritization outcomes and improve the generalizability of decision-support frameworks [131,155,156]. Therefore, future research may extend the proposed framework by incorporating alternative expert-response weighting schemes and comparing their effects on the prioritization of green behaviors among officer-class seafarers. Such comparative analyses would provide additional evidence regarding the stability, robustness, and transferability of the proposed decision framework across different expert panel configurations. Moreover, such analyses would complement the criterion-weight sensitivity analysis conducted in the present study by evaluating the influence of alternative expert-response

weighting assumptions on the final prioritization results, thereby providing a more comprehensive assessment of the robustness of the proposed IT2F-AHP framework.

Future research may compare the prioritization of green behaviors between shipboard officers and shore-based maritime managers by establishing separate expert panels for each stakeholder group. Since the present study included both operational and shore-based experts within a single evaluation panel, future studies could investigate whether the relative importance of sustainability dimensions and green behaviors differs across these stakeholder groups. Such comparative analyses would provide valuable insights into potential differences in sustainability priorities and help identify possible alignment or misalignment between shipboard and shore-based perspectives in implementing maritime sustainability strategies throughout shipping organizations.

In conclusion, this study advances the operationalization of sustainability in the shipping industry by transforming abstract environmental ideals into prioritized, evidence-based behavioral strategies.

Recognizing ship officers not as passive policy recipients but as proactive drivers of sustainable transformation marks a critical step toward a more responsible, resilient, and environmentally aligned maritime future.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su18147090/s1>, Table S1. Criteria; Table S2. Linguistic Pairwise Comparison Matrix for the Main Categories; Table S3. Aggregated IT2F Pairwise Comparison Decision Matrix for the Main Categories; Table S4. IT2F Fuzzy Weights, Normalized Weights, and Ranking for the Main Criteria; Table S5. Linguistic Pairwise Comparison Matrix for Criterion C1 (Environmental Sustainability); Table S6. Aggregated IT2F Decision Matrix for Criterion C1 (Environmental Sustainability); Table S7. IT2F Fuzzy Weights, Normalized Weights, Consistency Ratio (CR), and Ranking for Criterion C1 (Environmental Sustainability); Table S8. Linguistic Pairwise Comparison Matrix for Criterion C2 (Economic Sustainability); Table S9. Aggregated IT2F Decision Matrix for Criterion C2 (Economic Sustainability); Table S10. IT2F Fuzzy Weights, Normalized Weights, Consistency Ratio (CR), and Ranking for Criterion C2 (Economic Sustainability); Table S11. Linguistic Pairwise Comparison Matrix for Criterion C3 (Social Sustainability); Table S12. Aggregated IT2F Decision Matrix for Criterion C3 (Social Sustainability); Table S13. IT2F Fuzzy Weights, Normalized Weights, Consistency Ratio (CR), and Ranking for Criterion C3 (Social Sustainability).

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted in accordance with the ethical principles for research involving human participants and was approved by the Bandirma Onyedi Eylul University Ethics Committee for Social Sciences and Humanities (Approval Code: 2025-4; Approval Date: 27 March 2025).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available from the corresponding author upon reasonable request.

**Conflicts of Interest:** The author declares no conflicts of interest.

## References

1. United Nations Conference on Trade and Development. *Review of Maritime Transport 2023*; UNCTAD: Geneva, Switzerland, 2023.
2. International Maritime Organization (IMO). 2023 IMO Strategy on Reduction of GHG Emissions from Ships. 2023. Available online: <https://www.wcdn.imo.org/localresources/en/OurWork/Environment/Documents/annex/MEPC%2080/Annex%2015.pdf> (accessed on 12 January 2026).

3. Laporte, G. Sustainable shipping: A cross-disciplinary view. *Marit. Econ. Logist.* **2020**, *22*, 326–327. <https://doi.org/10.1057/s41278-020-00159-2>.
4. Lun, Y.V.; Lai, K.H.; Wong, C.W.; Cheng, T.E. *Green Shipping Management*; Springer: New York, NY, USA, 2016; pp. 17–29.
5. Camilleri, M.A. Corporate sustainability and responsibility: Creating value for business, society and the environment. *Asian J. Sustain. Soc. Responsib.* **2017**, *2*, 59–74. <https://doi.org/10.1186/s41180-017-0016-5>.
6. Dewan, M.H.; Godina, R. Roles and challenges of seafarers for implementation of energy efficiency operational measures onboard ships. *Mar. Policy* **2023**, *155*, 105746. <https://doi.org/10.1016/j.marpol.2023.105746>.
7. Akamangwa, N.I. Environmental Management at Sea: What Being ‘Green’ Means for Seafarers. In *The World of the Seafarer*; WMU Studies in Maritime Affairs; Springer: Cham, Switzerland, 2020; pp. 113–126. [https://doi.org/10.1007/978-3-030-49825-2\\_10](https://doi.org/10.1007/978-3-030-49825-2_10).
8. Dewan, M.H.; Godina, R. Unveiling seafarers’ awareness and knowledge on energy-efficient and low-carbon shipping: A decade of IMO regulation enforcement. *Mar. Policy* **2024**, *161*, 106037. <https://doi.org/10.1016/j.marpol.2024.106037>.
9. Robertson, J.L.; Barling, J. Greening organizations through leaders’ influence on employees’ pro-environmental behaviors. *J. Organ. Behav.* **2013**, *34*, 176–194. <https://doi.org/10.1002/job.1820>.
10. Paillé, P.; Mejía-Morelos, J.H.; Marché-Paillé, A.; Chen, C.C.; Chen, Y. Corporate greening, exchange process among co-workers, and ethics of care: An empirical study on the determinants of pro-environmental behaviors at coworkers-level. *J. Bus. Ethics* **2016**, *136*, 655–673. <https://doi.org/10.1007/s10551-015-2537-0>.
11. Zacher, H.; Rudolph, C.; Katz, I. Employee green behavior as the core of environmentally sustainable organizations. *Annu. Rev. Organ. Psychol. Organ. Behav.* **2023**, *10*, 465–494. <https://doi.org/10.1146/annurev-orgpsych-120920-050421>.
12. Brooks, S.K.; Greenberg, N. Mental health and psychological wellbeing of maritime personnel: A systematic review. *BMC Psychol.* **2022**, *10*, 139. <https://doi.org/10.1186/s40359-022-00850-4>.
13. Hasanspahić, N.; Frančić, V.; Vujičić, S.; Mandušić, M. Safety Leadership as a Means for Safe and Sustainable Shipping. *Sustainability* **2021**, *13*, 7841. <https://doi.org/10.3390/su13147841>.
14. Zoubir, M.; Schwarz, B.; Heidinger, J.; Gruner, M.; Jetter, H.C.; Franke, T. Anchoring autonomy: Understanding seafarers’ interaction with energy efficiency decision support systems for route planning and the role of basic psychological needs. *Cogn. Technol. Work* **2025**, *27*, 121–136. <https://doi.org/10.1007/s10111-025-00789-7>.
15. World Maritime University. Proceedings of WMU Maritime Week 2024: Bridging the Gap—Seafarer Behavior and Sustainability Execution. WMU Maritime Week. 2024. Available online: [https://commons.wmu.se/wmu\\_mw24/1/](https://commons.wmu.se/wmu_mw24/1/) (accessed on 12 January 2026).
16. Du, M.; Zhang, J.; Hou, X. Decarbonization like China: How does green finance reform and innovation enhance carbon emission efficiency? *J. Environ. Manag.* **2025**, *376*, 124331. <https://doi.org/10.1016/j.jenvman.2025.124331>.
17. Ali, A.; Huang, J. Trends and trajectories in employee green behavior research. *Front. Sociol.* **2024**, *9*, 1486377. <https://doi.org/10.3389/fsoc.2024.1486377>.
18. Akbaba, M.; Kara, E.; Özel, G.; Yakut, E.; Avcı, M.; Çetinel, M.H. Green Organisational Identity and Employees’ Green Behaviour: The Mediating Role of Environmental Commitment in Tourism Enterprises. *Sustainability* **2025**, *17*, 2837. <https://doi.org/10.3390/su17072837>.
19. Gaybullaev, O.; Strode, J.P. Transformational leadership and organizational sustainability performance: A systematic literature review of global evidence. *Environ. Dev. Sustain.* **2026**, 1–49. <https://doi.org/10.1007/s10668-026-07319-z>.
20. WCED (World Commission on Environment and Development). *Our Common Future*; Oxford University Press: Oxford, UK, 1987.
21. Brown, B.J.; Hanson, M.E.; Liverman, D.M.; Merideth, R.W. Global sustainability: Toward definition. *Environ. Manag.* **1987**, *11*, 713–719. <https://doi.org/10.1007/BF01867238>.
22. Purvis, B.; Mao, Y.; Robinson, D. Three pillars of sustainability: In search of conceptual origins. *Sustain. Sci.* **2019**, *14*, 681–695. <https://doi.org/10.1007/s11625-018-0627-5>.
23. Ejder, E.; Dinçer, S.; Arslanoglu, Y. Decarbonization strategies in the maritime industry: An analysis of dual-fuel engine performance and the carbon intensity indicator. *Renew. Sustain. Energy Rev.* **2024**, *200*, 114587. <https://doi.org/10.1016/j.rser.2024.114587>.
24. Lai, K.H.; Lun, V.Y.; Wong, C.W.; Cheng, T.C.E. Green shipping practices in the shipping industry: Conceptualization, adoption, and implications. *Resour. Conserv. Recycl.* **2011**, *55*, 631–638. <https://doi.org/10.1016/j.resconrec.2010.12.004>.
25. Kolios, A. Retrofitting Technologies for Eco-Friendly Ship Structures: A Risk Analysis Perspective. *J. Mar. Sci. Eng.* **2024**, *12*, 679. <https://doi.org/10.3390/jmse12040679>.

26. Norton, T.A.; Parker, S.L.; Zacher, H.; Ashkanasy, N.M. Employee green behavior. *Organ. Environ.* **2015**, *28*, 103–125. <https://doi.org/10.1177/1086026615575773>.
27. Chaudhary, R. green human resource management and employee green behavior: An empirical analysis. *Corp. Soc. Responsib. Environ. Manag.* **2020**, *27*, 630–641. <https://doi.org/10.1002/csr.1827>.
28. United Nations Conference on Trade and Development (UNCTAD). Decarbonizing Shipping: How to Speed the Transition and Ensure It's Fair. 2023. Available online: <https://unctad.org/news/decarbonizing-shipping-how-speed-transition-and-ensure-its-fair> (accessed on 12 January 2026).
29. European Commission. FuelEU Maritime: Reducing Greenhouse Gas Emissions from the Shipping Sector. Directorate-General for Mobility and Transport. 2023. Available online: [https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal\\_en](https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en) (accessed on 12 January 2026).
30. Ahmed, M.; Zehou, S.; Raza, S.A.; Qureshi, M.A.; Yousufi, S.Q. Impact of CSR and environmental triggers on employee green behavior: The mediating effect of employee well-being. *Corp. Soc. Responsib. Environ. Manag.* **2020**, *27*, 2225–2239. <https://doi.org/10.1002/csr.1960>.
31. He, J.; Morrison, A.; Zhang, H. Being sustainable: The three-way interactive effects of csr, green human resource management, and responsible leadership on employee green behavior and task performance. *Corp. Soc. Responsib. Environ. Manag.* **2020**, *28*, 1043–1054. <https://doi.org/10.1002/csr.2104>.
32. Yadate, D. The effect of green human resource management on employee green behavior. *Corp. Soc. Responsib. Environ. Manag.* **2024**, *32*, 404–418. <https://doi.org/10.1002/csr.2956>.
33. Karmoker, K.; Kona, F.; Oyshi, A.; Yasmin, K. Effects of green human resource management on employee green behavior: Moderating role of employee environmental knowledge. *Int. J. Sustain. Dev. World Policy* **2021**, *10*, 64–80. <https://doi.org/10.18488/journal.26.2021.102.64.80>.
34. Kotsopoulos, D.; Bardaki, C.; Papaioannou, T.G. Determinants of employees' personal and collective energy consumption and conservation at work. *Sustainability* **2023**, *15*, 4913. <https://doi.org/10.3390/su15064913>.
35. Tuan, L. Reducing food waste behavior among hospitality employees through communication: Dual mediation paths. *Int. J. Contemp. Hosp. Manag.* **2020**, *32*, 1881–1904. <https://doi.org/10.1108/ijchm-09-2019-0779>.
36. Cho, M.; Yoo, J. Customer pressure and restaurant employee green creative behavior: Serial mediation effects of restaurant ethical standards and employee green passion. *Int. J. Contemp. Hosp. Manag.* **2021**, *33*, 4505–4525. <https://doi.org/10.1108/ijchm-06-2021-0697>.
37. Edosomwan, H.S.; Oguebe, T.M.; Ogechukwu, J.C. Workplace well-being in manufacturing organizations in nigeria: Do employee green behavior, core self-evaluations and empowering leadership matter? *Int. J. Occup. Saf. Health* **2023**, *13*, 97–107. <https://doi.org/10.3126/ijosh.v13i1.42236>.
38. Kerse, G. The effect of perceived green organizational support on employee green behavior. *Braz. J. Oper. Prod. Manag.* **2024**, *21*, 1762. <https://doi.org/10.14488/bjopm.1762.2024>.
39. Khalid, B.; Shahzad, K.; Shafi, M.; Paillé, P. Predicting required and voluntary employee green behavior using the theory of planned behavior. *Corp. Soc. Responsib. Environ. Manag.* **2022**, *29*, 1300–1314. <https://doi.org/10.1002/csr.2270>.
40. Dumont, J.; Shen, J.; Deng, X. Effects of green hrm practices on employee workplace green behavior: The role of psychological green climate and employee green values. *Hum. Resour. Manag.* **2017**, *56*, 613–627. <https://doi.org/10.1002/hrm.21792>.
41. Saeed, B.; Afsar, B.; Hafeez, S.; Khan, I.; Tahir, M.; Afridi, M. Promoting employee's proenvironmental behavior through green human resource management practices. *Corp. Soc. Responsib. Environ. Manag.* **2018**, *26*, 424–438. <https://doi.org/10.1002/csr.1694>.
42. Ercantan, Ö.; Eyüpoğlu, Ş. How do green human resource management practices encourage employees to engage in green behavior? perceptions of university students as prospective employees. *Sustainability* **2022**, *14*, 1718. <https://doi.org/10.3390/su14031718>.
43. Rejeki, D.; Putra, M. Does green organizational identity mediate green human resource management on employee green behavior? *World J. Adv. Res. Rev.* **2024**, *21*, 710–720. <https://doi.org/10.30574/wjarr.2024.21.1.0077>.
44. Fang, L.; Zhan, X. Study of the bidirectional impact of corporate green performance management on employees' employee non-green behavior. *Front. Bus. Econ. Manag.* **2024**, *13*, 300–308. <https://doi.org/10.54097/pt2f9q96>.
45. Blazejewski, S.; Dittmer, F.; Buhl, A.; Barth, A.; Herbes, C. "That is not what I live for": How lower-level green employees cope with identity tensions at work. *Sustainability* **2020**, *12*, 5778. <https://doi.org/10.3390/su12145778>.
46. Sutarmim, S.; Yulianeu, A.; Darmawan, A.; Kurniawan, A. Driving sustainable change: Green transformational leadership, job crafting, and work engagement in frugal eco-innovation. *Int. J. Sustain. Dev. Plan.* **2023**, *18*, 3883–3893. <https://doi.org/10.18280/ijdp.181220>.

47. Olya, H.; Ahmad, M.; Abdulaziz, T.; Khairy, H.; Fayyad, S.; Lee, C. Catalyzing green change: The impact of tech-savvy leaders on innovative behaviors. *Corp. Soc. Responsib. Environ. Manag.* **2024**, *31*, 5543–5556. <https://doi.org/10.1002/csr.2871>.
48. Zafar, H.; Tian, F.; Ho, J.; Roh, T.; Latif, B. Understanding voluntary pro-environmental behavior among colleagues: Roles of green crafting, psychological empowerment, and green organizational climate. *Bus. Strategy Environ.* **2024**, *34*, 468–482. <https://doi.org/10.1002/bse.4001>.
49. Lathabhavan, R.; Bharti, T. Exploring the linkage of green values and green attitude in green behaviour: Moderating role of green climate among Indian employees. *Soc. Responsib. J.* **2024**, *20*, 2008–2024. <https://doi.org/10.1108/srj-01-2024-0035>.
50. Gupta, R.; Kaur, S. A 2-1-1 multi-level perspective of understanding the relationship between green human resource management practices, green psychological climate, and green employee behavior. *Corp. Soc. Responsib. Environ. Manag.* **2024**, *31*, 4068–4084. <https://doi.org/10.1002/csr.2778>.
51. Aukhoon, M.; Iqbal, J.; Parray, Z. Impact of corporate social responsibility on employee green behavior: Role of green human resource management practices and employee green culture. *Corp. Soc. Responsib. Environ. Manag.* **2024**, *31*, 3768–3778. <https://doi.org/10.1002/csr.2773>.
52. Gupta, A.; Singh, R. Managing operations by a logistics company for sustainable service quality: Indian perspective. *Manag. Environ. Qual. Int. J.* **2020**, *31*, 1309–1327. <https://doi.org/10.1108/meq-11-2019-0246>.
53. Fawehinmi, O.; Yusliza, M.Y.; Wan Kasim, W.Z.; Mohamad, Z.; Sofian Abdul Halim, M.A. Exploring the interplay of green human resource management, employee green behavior, and personal moral norms. *SAGE Open* **2020**, *10*, 2158244020982292. <https://doi.org/10.1177/2158244020982292>.
54. Farrukh, M.; Raza, A.; Ansari, N.; Bhutta, U. A bibliometric reflection on the history of green human resource management research. *Manag. Res. Rev.* **2021**, *45*, 781–800. <https://doi.org/10.1108/mrr-09-2020-0585>.
55. Liu, H.T. The influence of public servants' perceived formalism and organizational environmental strategy on green behavior in the workplace. *Sustainability* **2021**, *13*, 11020. <https://doi.org/10.3390/su131911020>.
56. Wang, J.; Tang, L.; Zhang, T.; Phillips, C.; Aldawish, L.S. The implementation and barriers of green recruitment: A qualitative study on green human resource management. *Businesses* **2024**, *4*, 411–425. <https://doi.org/10.3390/businesses4030025>.
57. Chowdhury, T.; Karim, R.A.; Rabiul, M.K.; Alam, M.U.; Karim, D.N. Fostering sustainable environmental performance through green banking practices: The mediating role of employees' green motivation and green behavior. *Sustainability* **2025**, *17*, 3750. <https://doi.org/10.3390/su17083750>.
58. Dos Santos, J.C.; Ribeiro, P.; Bento, R.J.S. A review of the promotion of sustainable mobility of workers by industries. *Sustainability* **2023**, *15*, 8508. <https://doi.org/10.3390/su15118508>.
59. Temminck, E.; Mearns, K.; Fruhen, L. Motivating employees towards sustainable behaviour. *Bus. Strategy Environ.* **2015**, *24*, 402–412. <https://doi.org/10.1002/bse.1827>.
60. Zarabi, Z.; Lord, S. Toward More Sustainable Behavior: A Systematic Review of the Impacts of Involuntary Workplace Relocation on Travel Mode Choice. *J. Plan. Lit.* **2018**, *34*, 38–58. <https://doi.org/10.1177/0885412218802467>.
61. Molina, J.A.; Giménez-Nadal, J.I.; Velilla, J. Sustainable commuting: Results from a social approach and international evidence on carpooling. *Sustainability* **2020**, *12*, 9587. <https://doi.org/10.3390/su12229587>.
62. Martinolli, G.; de Angelis, M.; Tordera, N.; Pietrantoni, L. The organizational climate for sustainable commuting: An Italian validation study in the academic sector. *Sustainability* **2021**, *13*, 9215. <https://doi.org/10.3390/su13169215>.
63. Whillans, A.; Sherlock, J.; Roberts, J.; O'Flaherty, S.; Gavin, L.; Dykstra, H.; Daly, M. Nudging the Commute: Using Behaviorally Informed Interventions to Promote Sustainable Transportation. *Behav. Sci. Policy* **2021**, *7*, 27–49. <https://doi.org/10.1177/237946152100700204>.
64. Eltayeb, T.K.; Zailani, S. Investigation on the drivers of green purchasing towards environmental sustainability in the Malaysian manufacturing sector. *Int. J. Procure. Manag.* **2010**, *3*, 316–333. <https://doi.org/10.1504/IJPM.2010.033448>.
65. Moser, A.K. Thinking green, buying green? Drivers of pro-environmental purchasing behavior. *J. Consum. Mark.* **2015**, *32*, 167–175. <https://doi.org/10.1108/JCM-10-2014-1179>.
66. Amoako, G.K.; Dzogbenuku, R.K.; Abubakari, A. Do green knowledge and attitude influence the youth's green purchasing? Theory of planned behavior. *Int. J. Product. Perform. Manag.* **2020**, *69*, 1609–1626. <https://doi.org/10.1108/IJPPM-12-2019-0595>.
67. Bonn, M.A.; Chun, Y.; Yoo, J.J.-E.; Cho, M. Green Purchasing by Wine Retailers: Roles of Individual Values, Competences and Organizational Culture. *Cornell Hosp. Q.* **2020**, *62*, 324–336. <https://doi.org/10.1177/1938965520978166>.
68. Casalegno, C.; Candelo, E.; Santoro, G. Exploring the antecedents of green and sustainable purchase behaviour: A comparison among different generations. *Psychol. Mark.* **2022**, *39*, 1007–1021. <https://doi.org/10.1002/mar.21637>.

69. Sabbir, M.M.; Taufique, K.M.R. Sustainable employee green behavior in the workplace: Integrating cognitive and non-cognitive factors in corporate environmental policy. *Bus. Strategy Environ.* **2022**, *31*, 110–128. <https://doi.org/10.1002/bse.2877>.
70. Etse, D.; Adu-Aboagye, A. Effect of green organisational climate on green purchasing: The roles of employee green behavioural intentions and corporate environmental communication. *Sustain. Futures* **2025**, *9*, 100419. <https://doi.org/10.1016/j.sftr.2024.100419>.
71. Safari, A.; Salehzadeh, R.; Panahi, R.; Abolghasemian, S. Multiple pathways linking environmental knowledge and awareness to employees' green behavior. *Corp. Gov. Int. J. Bus. Soc.* **2018**, *18*, 81–103. <https://doi.org/10.1108/cg-08-2016-0168>.
72. Ahmad, S.; Islam, T.; Sadiq, M.; Kaleem, A. Promoting green behavior through ethical leadership: A model of green human resource management and environmental knowledge. *Leadersh. Organ. Dev. J.* **2021**, *42*, 531–547. <https://doi.org/10.1108/LODJ-01-2020-0024>.
73. Unsworth, K.L.; Davis, M.C.; Russell, S.V.; Bretter, C. Employee green behaviour: How organizations can help the environment. *Curr. Opin. Psychol.* **2021**, *42*, 1–6. <https://doi.org/10.1016/j.copsyc.2020.12.006>.
74. Zhang, W.; Xu, R.; Jiang, Y.; Zhang, W. How environmental knowledge management promotes employee green behavior: An empirical study. *Int. J. Environ. Res. Public Health* **2021**, *18*, 4738. <https://doi.org/10.3390/ijerph18094738>.
75. Darvishmotevali, M.; Altinay, L. Green HRM, environmental awareness and green behaviors: The moderating role of servant leadership. *Tour. Manag.* **2022**, *88*, 104401. <https://doi.org/10.1016/j.tourman.2021.104401>.
76. Li, Z.; Yu, H.; Xing, L. The impact of green culture on employees' green behavior: The mediation role of environmental awareness. *Corp. Soc. Responsib. Environ. Manag.* **2023**, *30*, 1325–1335. <https://doi.org/10.1002/csr.2422>.
77. Usman, M.; Rofcanin, Y.; Ali, M.; Ogbonnaya, C.; Babalola, M.T. Toward a more sustainable environment: Understanding why and when green training promotes employees' eco-friendly behaviors outside of work. *Hum. Resour. Manag.* **2023**, *62*, 355–371. <https://doi.org/10.1002/hrm.22148>.
78. Tang, G.; Ren, S.; Wang, M.; Li, Y.; Zhang, S. Employee green behaviour: A review and recommendations for future research. *Int. J. Manag. Rev.* **2023**, *25*, 297–317. <https://doi.org/10.1111/ijmr.12328>.
79. Zhang, B.; Yang, L.; Cheng, X.; Chen, F. How Does Employee Green Behavior Impact Employee Well-Being? An Empirical Analysis. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1669. <https://doi.org/10.3390/ijerph18041669>.
80. Nasir Ansari, J.A.; Irfan, S. Corporate social responsibility and employee engagement: The mediating role of personal environmental norms and employee green behavior. *Soc. Responsib. J.* **2023**, *19*, 1728–1748. <https://doi.org/10.1108/SRJ-03-2022-0153>.
81. Veerasamy, U.; Joseph, M.S.; Parayitam, S. Green Human Resource Management and Employee Green Behaviour: Participation and Involvement, and Training and Development as Moderators. *S. Asian J. Hum. Resour. Manag.* **2023**, *11*, 277–309. <https://doi.org/10.1177/23220937221144361>.
82. Rubel, M.R.B.; Kee, D.M.H.; Rimi, N.N. Unpacking the eco-friendly path: Exploring organizational green initiatives, green perceived organizational support and employee green behavior. *Int. J. Contemp. Hosp. Manag.* **2025**, *37*, 2049–2071. <https://doi.org/10.1108/IJCHM-03-2024-0460>.
83. Usman, M.; Akhtar, M.W.; Zahoor, N.; Khan, M.A.S.; Adomako, S. Triggering employee green activism through green human resource management: The role of green organizational learning and responsible leadership. *Bus. Strategy Environ.* **2025**, *34*, 1085–1096. <https://doi.org/10.1002/bse.4028>.
84. Haque, S.; Panda, D.; Ghosh, A. Gamifying sustainability with self-efficacy: Motivating green behaviours in large industrial firms. *Int. J. Organ. Anal.* **2024**, *32*, 74–93. <https://doi.org/10.1108/IJOA-08-2023-3951>.
85. Aboramadan, M.; Kundi, Y.M.; Farao, C. Examining the effects of environmentally-specific servant leadership on green work outcomes among hotel employees: The mediating role of climate for green creativity. *J. Hosp. Mark. Manag.* **2021**, *30*, 929–956. <https://doi.org/10.1080/19368623.2021.1912681>.
86. Sobaih, A.E.E.; Hasanein, A.; Gharbi, H.; Abu Elnasr, A.E. Going Green Together: Effects of Green Transformational Leadership on Employee Green Behaviour and Environmental Performance in the Saudi Food Industry. *Agriculture* **2022**, *12*, 1100. <https://doi.org/10.3390/agriculture12081100>.
87. Afridi, S.A.; Javed, A.; Ali, S.Z.; Zafar, S.; Haider, M. Cultivating Sustainability: The Role of Generative Leadership, Green Passion, and Green Work Behavior in Pakistan's Tourism Industry. *Sustainability* **2023**, *15*, 14139. <https://doi.org/10.3390/su151914139>.
88. Yan, L.; Ahmed, Z.; Khosa, M.; Fahmi Omar Faqera, A.; Kayode Ibikunle, A.; Rashid Khan, A. Entrepreneurial Leadership and Green Innovative Work Behavior: The Role of Green Soft and Hard Talent Management with a Dual Theoretical Lens. *Sustainability* **2024**, *16*, 8136. <https://doi.org/10.3390/su16188136>.

89. Owusu, E.A.; Zhou, L.; Sarpong, F.A.; Sampene, A.K.; Antwi, H.A.; Arboh, F.; Yunus, A. Exploring the Impact of Green Performance on Employees' Pro-Environmental Behaviors: A Multi-Group Analysis from Developed and Emerging Economies Healthcare Industries. *Bus. Strategy Environ.* **2025**, *34*, 4717–4746. <https://doi.org/10.1002/bse.4228>.
90. Ahmed, F.; Callaghan, D.; Arslan, A. A multilevel conceptual framework on green practices: Transforming policies into actionable leadership and employee behavior. *Scand. J. Psychol.* **2023**, *65*, 381–393. <https://doi.org/10.1111/sjop.12981>.
91. Ali, M.; Shujahat, M.; Fatima, N.; Jabbour, A.; Vo-Thanh, T.; Salam, M.; Latan, H. Green HRM practices and corporate sustainability performance. *Manag. Decis.* **2024**, *62*, 3681–3703. <https://doi.org/10.1108/md-05-2023-0787>.
92. Hsieh, C.; Wang, D. Does supervisor-perceived authentic leadership influence employee work engagement through employee-perceived authentic leadership and employee trust? *Int. J. Hum. Resour. Manag.* **2015**, *26*, 2329–2348. <https://doi.org/10.1080/09585192.2015.1025234>.
93. Tang, G.; Chen, Y.; Jiang, Y.; Paillé, P.; Jia, J. Green human resource management practices: Scale development and validity. *Asia Pac. J. Hum. Resour.* **2017**, *56*, 31–55. <https://doi.org/10.1111/1744-7941.12147>.
94. Bissing-Olson, M.J.; Iyer, A.; Fielding, K.S.; Zacher, H. Relationships between daily affect and pro-environmental behavior at work: The moderating role of pro-environmental attitude. *J. Organ. Behav.* **2012**, *34*, 156–175. <https://doi.org/10.1002/job.1788>.
95. International Maritime Organization (IMO). Initial IMO Strategy on Reduction of GHG Emissions from Ships (Resolution MEPC.304(72)). 2018. Available online: [https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Resolution%20MEPC.304\(72\)\\_E.pdf](https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Resolution%20MEPC.304(72)_E.pdf) (accessed on 12 January 2026).
96. Bhattacharya, C.; Sen, S.; Edinger-Schons, L.M.; Neureiter, M. Corporate purpose and employee sustainability behaviors. *J. Bus. Ethics* **2022**, *183*, 963–981. <https://doi.org/10.1007/s10551-022-05090-5>.
97. Young, W.; Davis, M.; McNeill, I.M.; Malhotra, B.; Russell, S.; Unsworth, K.; Clegg, C.W. Changing behaviour: Successful environmental programmes in the workplace. *Bus. Strategy Environ.* **2013**, *24*, 689–703. <https://doi.org/10.1002/bse.1836>.
98. Strauss, K.; Lepoutre, J.; Wood, G. Fifty shades of green: How microfoundations of sustainability dynamic capabilities vary across organizational contexts. *J. Organ. Behav.* **2017**, *38*, 1338–1355. <https://doi.org/10.1002/job.2186>.
99. Schröder, S.; Wiek, A.; Farny, S.; Luthardt, P. Toward holistic corporate sustainability—Developing employees' action competence for sustainability in small and medium-sized enterprises through training. *Bus. Strategy Environ.* **2022**, *32*, 1650–1669. <https://doi.org/10.1002/bse.3210>.
100. Huang, C.; Chang, T.; Ting, C.; Huang, S. How does organizational leadership promote pro-environmental behavior? A moderated mediation model of environmental corporate social responsibility policies. *Sustainability* **2024**, *16*, 4716. <https://doi.org/10.3390/su16114716>.
101. Essel, D.; Jin, Z.; Bowers, J.O.; Abdul-Salam, R. Green maritime practices in an emerging economy towards the achievement of sustainable development: A Ghanaian context. *Benchmarking Int. J.* **2023**, *30*, 3637–3673. <https://doi.org/10.1108/bij-10-2021-0629>.
102. Chauvin, C.; Clostermann, J.P.; Hoc, J.M. Impact of training programs on decision-making and situation awareness of trainee watch officers. *Saf. Sci.* **2009**, *47*, 1222–1231. <https://doi.org/10.1016/j.ssci.2009.03.008>.
103. Wu, B.; Yan, X.; Wang, Y.; Zhang, D.; Guedes Soares, C. Three-stage decision-making model under restricted conditions for emergency response to ships not under control. *Risk Anal.* **2017**, *37*, 2455–2474. <https://doi.org/10.1111/risa.12815>.
104. Bodhi, R.; Chaturvedi, S.; Purohit, S. The influence of organizational commitment on employee green behavior: Mediating role of work-related social media use. *Int. J. Manpow.* **2024**, *46*, 605–631. <https://doi.org/10.1108/IJM-10-2023-0624>.
105. Xue, Y.; Lai, K.H. Digital green shipping innovation: Conception, adoption, and challenges. *J. Glob. Inf. Manag.* **2024**, *32*, 1–28. <https://doi.org/10.4018/jgim.349929>.
106. Ozkan, S.; Tari Selcuk, K.; Kan, Z.E. Is green behaviors of health professionals related to green practices in the workplace? Multi-center study in Turkey. *Int. J. Environ. Health Res.* **2024**, *34*, 898–910. <https://doi.org/10.1080/09603123.2023.2185209>.
107. Okoli, C.; Pawlowski, S.D. The Delphi method as a research tool: An example, design considerations and applications. *Inf. Manag.* **2004**, *42*, 15–29. <https://doi.org/10.1016/j.im.2003.11.002>.
108. Paré, G.; Cameron, A.F.; Poba-Nzaou, P.; Templier, M. A systematic assessment of rigor in information systems ranking-type Delphi studies. *Inf. Manag.* **2013**, *50*, 207–217. <https://doi.org/10.1016/j.im.2013.03.003>.
109. Linstone, H.A.; Turoff, M. *The Delphi Method: Techniques and Applications*; Addison-Wesley: Boston, MA, USA, 2002.
110. Chen, Z.; Pak, M. A Delphi analysis on green performance evaluation indices for ports in China. *Marit. Policy Manag.* **2017**, *44*, 537–550. <https://doi.org/10.1080/03088839.2017.1327726>.
111. Kahraman, C.; Öztayşi, B.; Sarı, İ.U.; Turanoğlu, E. Fuzzy analytic hierarchy process with interval type-2 fuzzy sets. *Knowl.-Based Syst.* **2014**, *59*, 48–57. <https://doi.org/10.1016/j.knosys.2014.02.001>.

112. Sari, K. A novel multi-criteria decision framework for evaluating green supply chain management practices. *Comput. Ind. Eng.* **2017**, *105*, 338–347. <https://doi.org/10.1016/j.cie.2017.01.016>.
113. Mendel, J.M.; John, R.I. Type-2 fuzzy sets made simple. *IEEE Trans. Fuzzy Syst.* **2002**, *10*, 117–127. <https://doi.org/10.1109/91.995115>.
114. Kumar, M.; Biswas, S.; Kar, S.; Božanić, D.; Puška, A. An Interval Type 2 Fuzzy Decision-Making Framework for Exploring Critical Issues for the Sustenance of the Tea Industry. *Axioms* **2023**, *12*, 986. <https://doi.org/10.3390/axioms12100986>.
115. Celik, E.; Gül, M.; Aydın, N.; Gümüş, A.T.; Güneri, A.F. A comprehensive review of multi-criteria decision-making approaches based on interval type-2 fuzzy sets. *Knowl.-Based Syst.* **2015**, *85*, 329–341. <https://doi.org/10.1016/j.knsys.2015.06.004>.
116. Akan, E.; Kiraci, K. A novel depreciation approach in an uncertain environment: Interval type-2 fuzzy sets in the maritime industry. *Soft Comput.* **2023**, *27*, 1941–1969. <https://doi.org/10.1007/s00500-022-06778-6>.
117. Gulen, M.F.; Uflaz, E.; Gumus, F.; Orhan, M.; Arslan, O. An integrated SWOT-based interval type-2 fuzzy AHP and TOPSIS methodology for digital transformation strategy selection in maritime safety. *Ocean Eng.* **2025**, *323*, 120518. <https://doi.org/10.1016/j.oceaneng.2025.120518>.
118. Dajani, J.S.; Sincoff, M.Z.; Talley, W.K. Stability and agreement criteria for the Delphi technique. *Technol. Forecast. Soc. Change* **1979**, *13*, 83–90. [https://doi.org/10.1016/0040-1625\(79\)90007-6](https://doi.org/10.1016/0040-1625(79)90007-6).
119. Gupta, U.G.; Clarke, R.E. Theory and applications of the Delphi technique: A bibliography (1975–1994). *Technol. Forecast. Soc. Change* **1996**, *53*, 185–211. [https://doi.org/10.1016/S0040-1625\(96\)00094-7](https://doi.org/10.1016/S0040-1625(96)00094-7).
120. Dirzka, C.; Acciaro, M. Principal-agent problems in decarbonizing container shipping: A panel data analysis. *Transp. Res. Part D Transp. Environ.* **2021**, *98*, 102948. <https://doi.org/10.1016/j.trd.2021.102948>.
121. Hellström, M.; Rabetino, R.; Schwartz, H.; Tsvetkova, A.; Haq, S.H.U. GHG emission reduction measures and alternative fuels in different shipping segments and time horizons—A Delphi study. *Mar. Policy* **2024**, *160*, 105997.
122. Garrido Salsas, J.; Saurí, S.; Raventós, E.; Rúa, C.; Torrent, J. Emerging trends defining the future role of ports: Application of the Delphi method. *Transp. Res. Rec.* **2022**, *2676*, 571–585.
123. Yalcin, E.; Arslan, O.; Aymelek, M. Developing a policy management algorithm for ship provision: A Delphi Technique Integrated with Hesitant Fuzzy Set (DTIHFS) approach. *Marit. Policy Manag.* **2020**, *47*, 1097–1118. <https://doi.org/10.1080/03088839.2020.1766142>.
124. Akyar, D.A.; Çetin, İ.B. Understanding the determinants of fleet size optimization in dry bulk shipping: Insights from a systematic literature review and Delphi study. *Marit. Policy Manag.* **2025**, *53*, 586–619. <https://doi.org/10.1080/03088839.2025.2514015>.
125. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; Wisdom, J.P.; Duan, N.; Hoagwood, K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Adm. Policy Ment. Health Ment. Health Serv. Res.* **2015**, *42*, 533–544. <https://doi.org/10.1007/s10488-013-0528-y>.
126. Strasser, A. Delphi method variants in information systems research: Taxonomy development and application. *Electron. J. Bus. Res. Methods* **2017**, *15*, 120–133.
127. Malekinezhad, K.M.; Rahimnia, F.; Eslami, G.; Farahi, M.M. Human resource analytics adoption: A framework-based analysis, fuzzy Delphi method and fuzzy SWARA. *J. Adv. Manag. Res.* **2025**, *22*, 597–627. <https://doi.org/10.1108/JAMR-05-2024-0181>.
128. Laine, V.; Valdez-Banda, O.; Goerlandt, F. Risk maturity model for the maritime authorities: A Delphi study to design the R-Mare matrix model. *WMU J. Marit. Aff.* **2024**, *23*, 137–163. <https://doi.org/10.1007/s13437-023-00328-z>.
129. Bostoooghli, A.; Saraceni, A. Transferability of green port strategies: A Delphi study with European ports. *J. Int. Marit. Saf. Environ. Aff. Shipp.* **2025**, *9*, 2454764. <https://doi.org/10.1080/25725084.2025.2454764>.
130. Arıcan, O.H.; Toprakçı, O.; Ünal, A.U.; Özbağ, G.K. Analyzing Carbon Regulation Impacts on Maritime Sector Using Fuzzy Delphi–DEMATEL–ISM Approach. *Systems* **2025**, *13*, 955. <https://doi.org/10.3390/systems13110955>.
131. Govindan, K.; Dua, R.; Anwar, A.M.; Bansal, P. Enabling net-zero shipping: An expert review-based agenda for emerging techno-economic and policy research. *Transp. Res. Part E Logist. Transp. Rev.* **2024**, *192*, 103753. <https://doi.org/10.1016/j.tre.2024.103753>.
132. Mayring, P. Qualitative content analysis. *Forum Qual. Soc. Res.* **2000**, *1*, 20. <https://doi.org/10.17169/fqs-1.2.1089>.
133. Krippendorff, K. *Content Analysis: An Introduction to Its Methodology*, 2nd ed.; Sage: Thousand Oaks, CA, USA, 2004.
134. Elo, S.; Kyngäs, H. The qualitative content analysis process. *J. Adv. Nurs.* **2008**, *62*, 107–115. <https://doi.org/10.1111/j.1365-2648.2007.04569.x>.
135. Yildiz, R.O.; Bastug, S.; Esmer, S. Talent management functions: A qualitative research on container shipping industry. *Int. J. Shipp. Transp. Logist.* **2023**, *16*, 320–359. <https://doi.org/10.1504/IJSTL.2023.129875>.

136. Yildiz, R.O.; Esmer, S. Talent management related concepts and debates in container shipping industry by an emerging market perspective. *J. Shipp. Trade* **2021**, *6*, 6. <https://doi.org/10.1186/s41072-021-00090-6>.
137. Hasson, F.; Keeney, S.; McKenna, H.P. Research guidelines for the Delphi survey technique. *J. Adv. Nurs.* **2000**, *32*, 1008–1015. <https://doi.org/10.1046/j.1365-2648.2000.t01-1-01567.x>.
138. Von der Gracht, H.A. Consensus measurement in Delphi studies. *Technol. Forecast. Soc. Change* **2012**, *79*, 1525–1536. <https://doi.org/10.1016/j.techfore.2012.04.013>.
139. Landeta, J. Current validity of the Delphi method in social sciences. *Technol. Forecast. Soc. Change* **2006**, *73*, 467–482. <https://doi.org/10.1016/j.techfore.2005.09.002>.
140. Schmidt, R.C. Managing Delphi surveys using nonparametric statistical techniques. *Decis. Sci.* **1997**, *28*, 763–774. <https://doi.org/10.1111/j.1540-5915.1997.tb01330.x>.
141. Van Laarhoven, P.J.; Pedrycz, W. A fuzzy extension of Saaty's priority theory. *Fuzzy Sets Syst.* **1983**, *11*, 229–241. [https://doi.org/10.1016/S0165-0114\(83\)80082-7](https://doi.org/10.1016/S0165-0114(83)80082-7).
142. Chang, D.Y. Applications of the extent analysis method on fuzzy AHP. *Eur. J. Oper. Res.* **1996**, *95*, 649–655. [https://doi.org/10.1016/0377-2217\(95\)00300-2](https://doi.org/10.1016/0377-2217(95)00300-2).
143. Kahraman, C.; Cebeci, U.; Ruan, D. Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey. *Int. J. Prod. Econ.* **2004**, *87*, 171–184. [https://doi.org/10.1016/S0925-5273\(03\)00099-9](https://doi.org/10.1016/S0925-5273(03)00099-9).
144. Wang, T.C.; Chen, Y.H. Applying fuzzy linguistic preference relations to the improvement of consistency of fuzzy AHP. *Inf. Sci.* **2008**, *178*, 3755–3765. <https://doi.org/10.1016/j.ins.2008.05.028>.
145. Chan, F.T.; Kumar, N.; Tiwari, M.K.; Lau, H.C.; Choy, K. Global supplier selection: A fuzzy-AHP approach. *Int. J. Prod. Res.* **2008**, *46*, 3825–3857. <https://doi.org/10.1080/00207540600787200>.
146. Dagdeviren, M.; Yuksel, I. Developing a fuzzy analytic hierarchy process (AHP) model for behavior-based safety management. *Inf. Sci.* **2008**, *178*, 1717–1733. <https://doi.org/10.1016/j.ins.2007.10.016>.
147. Chou, Y.C.; Sun, C.C.; Yen, H.Y. Evaluating the criteria for human resource for science and technology (HRST) based on an integrated fuzzy AHP and fuzzy DEMATEL approach. *Appl. Soft Comput.* **2012**, *12*, 64–71. <https://doi.org/10.1016/j.asoc.2011.08.058>.
148. Gupta, S.M.; Ilgin, M. *Multiple Criteria Decision-Making Applications in Environmentally Conscious Manufacturing and Product Recovery*; CRC Press: Boca Raton, FL, USA, 2017. <https://doi.org/10.1201/9781315119304>.
149. Noor, A.Z.M.; Fauadi, M.H.F.M.; Zulkifli, N.Z.H.; Naqib, M.; Basit, A.; Jafar, F.A.; Mohamad, N.R. Computation of fuzzy analytic hierarchy process (FAHP) using MATLAB programming in sustainable supply chain. *Int. J. Eng. Technol.* **2018**, *7*, 82–86. <https://doi.org/10.14419/ijet.v7i3.20.18985>.
150. Soner, C.; Celik, E.; Akyuz, E. Application of AHP and VIKOR under interval type-2 fuzzy environment in maritime transportation. *Ocean Eng.* **2017**, *129*, 107–117. <https://doi.org/10.1016/j.oceaneng.2016.11.010>.
151. Celik, E.; Akyuz, E. An interval type-2 fuzzy AHP and TOPSIS methods for decision-making problems in maritime transportation engineering: The case of ship loader. *Ocean Eng.* **2018**, *155*, 371–381. <https://doi.org/10.1016/j.oceaneng.2018.01.039>.
152. Saaty, T.L. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*; McGraw-Hill: New York, NY, USA, 1980.
153. Chiao, K. Trapezoidal interval type-2 fuzzy set extension of analytic hierarchy process. In *Proceedings of the 2012 IEEE World Congress on Computational Intelligence*; IEEE: New York, NY, USA, 2012; pp. 1–6. <https://doi.org/10.1109/FUZZ-IEEE.2012.6251342>.
154. Abdullah, L.; Najib, L. A new type-2 fuzzy set of linguistic variables for the fuzzy analytic hierarchy process. *Expert Syst. Appl.* **2014**, *41*, 3297–3305. <https://doi.org/10.1016/j.eswa.2014.02.007>.
155. Boix-Cots, D.; Pardo-Bosch, F.; Pujadas, P. A systematic review on multi-criteria group decision-making methods based on weights: Analysis and classification scheme. *Inf. Fusion* **2023**, *96*, 16–36. <https://doi.org/10.1016/j.inffus.2023.03.004>.
156. Dua, R.; Almutairi, S.; Bansal, P. Emerging energy economics and policy research priorities for enabling the electric vehicle sector. *Energy Rep.* **2024**, *12*, 1836–1847. <https://doi.org/10.1016/j.egyr.2024.08.001>.

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.