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Strategic Investment and Decision-Making in Greek Ports: A Socio-Economic Analysis of Seminar Impacts

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Abstract

Limiting global temperature rise to well below 2°C—ideally 1.5°C—is central to the Paris Agreement; however, recent projections by the United Nations Environment Programme (UNEP) suggest that current trajectories place the world on course for over 3°C of warming by the end of the century. Ports play a critical dual role in this climate crisis. On one hand, they contribute to greenhouse gas emissions through port operations, waste management, and worker mobility. On the other, they are highly vulnerable to climate impacts such as sea level rise and changing wave dynamics, which threaten the integrity of infrastructure and disrupt the global flow of goods—80–90% of which pass through ports. This study investigates the effectiveness of a targeted seminar series implemented in 2023 to enhance the understanding of sustainable development principles among Greek port stakeholders, including port authorities, municipal port funds, and marina operators. The seminars aimed to build capacity in areas such as blue growth, green energy, circular economy, and digital transitions. In addition, this research captures stakeholder preferences for climate mitigation and adaptation technological solutions through a DCE. Solutions presented were drawn from the MENA Maritime Accelerator and grouped into five key action areas: circular economy, clean energy production and storage, water quality, and air quality. The findings contribute to assessing both the awareness-raising potential of such training interventions and the prioritisation of climate-resilient innovations in the port sector.

Key words: ports infrastructure, pairwise comparison, innovations, decision-making, climate change

1. Introduction

Since the industrial revolution, the quantity of greenhouse gases (GHG) emitted into the atmosphere has significantly increased. The greenhouse effect is a natural phenomenon, and without it, temperatures on Earth would be approximately 33 degrees Celsius colder than they are today. When humans emit greenhouse gases, they create an "overeffect" that contributes to global warming. Carbon dioxide (CO_2) (responsible for 80% of human-caused emissions), methane (CH_4), oxide of nitrogen (N_2O), and fluorinated gases are the four primary greenhouse gases (IPCC, 1992). The increase in these GHG emissions causes global warming, which has consequences for the ocean and cryosphere. Due to thermal expansion of the ocean and the thawing of polar regions and high mountains, this increase in temperature is causing sea level rise (SLR). As a consequence of the rising temperatures, both the magnitude and frequency of extreme events are expanding. This is concurrently causing negative effects on water quality, ecosystems, and cultures of diverse ethnicities, as well as significant damage to human infrastructure and social and economic losses (IPCC, 2019).

Depending on future GHG emissions, a 2°C increase in global temperature, widely regarded as the threshold beyond which climate change risks may become intolerably high, may be reached by the 2050s. Despite a brief emission dip caused by the COVID-19 pandemic and indications of increased ambition in many countries, the latest UNEP Emissions Gap Report indicates that the world is still on track for a temperature rise of more than 3°C this century – well beyond the Paris Agreement goals of limiting global warming to well below 2°C and pursuing a limit of 1.5°C (UNEP, 2022).

Infrastructure, environment, population, safety and occupational health, and supply chains are the five major aspects of port operations that will be impacted by climate change, according to (Nursey-Bray et al., 2013). For the Mediterranean Ports, Portillo Juan et al. (2022) states that sea level rise, due to Climate Change, will affect the water depths of ports and inevitably alter wave propagation patterns, which may have repercussions for the stability of infrastructure. Flow-on effects that may affect the port's operating environment are also probable. For instance, increased inundation may lead to increased siltation within the port, necessitating more frequent dredging operations. As a result, dredged material may be transported to dredge spoil areas more frequently, thereby increasing the exposure of dredge spoil areas to invasive marine species that are translocated in the spoil (Nursey-Bray et al., 2013).

Coastal cities and ports are key for the current society and global economy. As trade continues to expand, it directly stimulates the economic growth of cities that manage cargo traffic. Their importance as economic hubs is increasing and they are becoming places where large parts of the population congregate and create economic and social value. Ports also play a strategic role for economic growth and development in all scales, whether global, regional or local. They are key transportation nodes for goods, they link local and national supply chains to global markets and are responsible for 80–90% of transportation of goods (Camus et al., 2019). Consequently, there will be significant social and economic repercussions if ports are impacted by a problem that inhibits their operation (Chhetri et al., 2014).

There are two primary strategies for avoiding climate change effects: mitigation and adaptation. The focus of mitigation strategies is on reducing emissions, whereas the focus of adaptation strategies is on adjusting existing systems to the anticipated effects of these emissions (IPCC, 2007). Even if the world ceased emitting greenhouse gases immediately, sea levels would continue to rise, and the frequency of extreme events would increase. Consequently, it is crucial for the future to define appropriate adaptation plans.

The World Association for Waterborne Transport Infrastructure (PIANC) released a Guideline for Port Authorities in 2014. This guideline addressed seven important issues, including climate change mitigation and adaptation (PIANC, 2014). While in 2020, PIANC Working Group 178 released a technical guidance document to assist the owners, administrators, and consumers of waterborne transport infrastructure in adapting to climate change (PIANC, 2020).

The main objective of this study is to ascertain the preferences of port and marina administrations regarding climate change adaptation and mitigation using a paired comparison experiment. Therefore, this study aims to address the following research questions:
RQ1. *To what degree have the seminars influenced participants' comprehension of the fundamental concepts of sustainable development within the framework of port operations?*
RQ2. *What are the stakeholders' interests and priorities for innovative solutions for port climate resilience in the five specified domains: circular economy, clean energy production, energy storage, water quality, and air quality?*
RQ3. *What types of climate-related technologies are regarded as the most actionable or effective for port infrastructure and operations in the Mediterranean region?*
RQ4. *How the socio-demographics and participation to the seminars has affected the perception of stakeholders from port authorities, local port funds, and marina management businesses regarding the significance and efficacy of suggested climate change adaptation and mitigation solutions?*

The article is organised as follows. The subsequent section offers a literature review of the subject matter. An explanation of the experimental design is presented, followed by the model employed. The data collection and the results are presented in the subsequent section, followed by a discussion section, and ultimately, conclusions are presented.

2. Literature Review

Becker et al. (2011) conducted a global survey of ports in 2010 to determine how port authority representatives perceived the potential impact of climate change on their operations and the adaptation measures in place. It is remarkable that the vast majority of ports viewed adaptation to climate change as an issue that the port community should address, yet only 34 per cent felt adequately informed. The climate variable that respondents were most concerned about was sea-level rise (SLR) (52 percent). To visualize and map the vulnerability of port operational assets to sea-level rise, Chhetri et al. (2014) developed a 3D model using high-resolution LiDAR and aerial imagery databases, as well as field survey data.

Apart of SLR, Nursey-Bray et al. (2013) present several other impacts associated with climate induced, as presented in Table 1. In terms of actual and prospective impacts, they revealed that climate-induced change poses a threat to ports in five key areas: (1) environment; (2) infrastructure; (3) ports and people; (4) occupational health and safety (OH&S); and (5) supply chain logistics. To adapt to these changes, ports rely on the ability of the industry to change over time; the social resilience of the system; and industry-initiated adaptation options.

Table 1 - Observed and anticipated variations in a variety of climate change observations (IPCC, 2007) *and their likely impact on the port sector. Source:* (Nursey-Bray et al., 2013)

Climate Change Observation	Observed changes (to date)	Projected changes: from present to 2100*	Likely (direct) impact on ports
Sea level	Rise of 1.8 $\pm$ 0.5 mm yr^{-1} since 1960	Rise of 0.18–0.59 m, least increase in the southern oceans and parts of North Atlantic Ocean	Storm surges, inundation and flooding of ports, insurance costs, OH&S issues
Land surface air temperature	Increase of 0.74°C ($\pm$0.18°C) in past 100 yr	Increase of between 1.1–6.4°C	Increased bio-deterioration resulting in higher maintenance costs
Precipitation	Increase in eastern North and South America, northern Europe and northern and central Asia	Increases at high latitudes, decreases in many subtropical regions	Changes to run-off & siltation, increased dredging, OH&S issues for port workers
Snow cover, permafrost, seasonally frozen ground	Decrease in all e.g. seasonally frozen ground in Northern Hemisphere decreased by 7%	Substantial decrease in all	Restricted to high latitude ports; not relevant to Australian ports
Sea ice extent, glaciers, ice caps	Decrease in annual and summer minimum levels	Substantial decrease in all, large parts of Arctic Ocean will no longer have year-round ice cover, no widespread melting in Antarctica	Changes to navigation routes, or development of new ports in high latitude regions; not relevant to Australian trade
Cold days/nights	Decrease in number	50–100% decline in cold air outbreaks	Negligible impact on ports sector
Warm days/nights	Increase in number	More frequent	Negligible impact on ports sector
Sea surface Temperature	Increase of ~0.6°C since 1955	Increase by 2.5°C, main increase in central and eastern equatorial Pacific	Migration of fish stocks changing the social use of ports; possible relocation of ports due to changing needs; increase in invasive species introductions and outbreak
Altered wind-speeds/loads	Limited change or slight reduction – based on limited data**	Increases associated with extreme events	Increased problems navigating narrow channels, increased costs for larger tugs to assist vessel manoeuvrability

Table 2 – (continued)

Climate Change Observation	Observed changes (to date)	Projected changes: from present to 2100*	Likely (direct) impact on ports
Ocean circulation/currents	Atlantic and southern polar front jet streams moved polewards, strengthening of westerly winds	Changes to Atlantic circulation	Changes to shipping routes; unlikely to significantly affect Australian trade
Ocean acidity	Increase in acidic (surface pH decrease of 0.1 units)	Increase in acidity (surface pH decrease by 0.14–0.35 units)	Increased corrosion, biodeterioration resulting in higher maintenance costs
Extreme meteorological events	More frequent	Storm tracks move poleward with associated changes in wind, precipitation and temperature	General issues for extreme events include: increased time vessels waiting to enter port, disruption of transport (road and rail) to ports; relocation of ports due to changing navigation routes, increase in insurance costs, OH&S considerations
Tropical storms (e.g. cyclones, hurricanes, typhoons)	Increase in intensity	Increase in intensity – but fewer of them – further penetration at higher latitudes	Increased wind speeds = damage to structures, engineering upgrades to structures & cargo handling equipment required
Heavy precipitation events	Increase in number	Increase in heavy daily rainfall events in many regions	Coastal flooding in port cities, increased run-off, disruption of transport (road and rail) to ports; siltation, heavy metals & pollutants entering ports, increased dredging
Heat waves	Increase in duration	90% increase in many tropical areas, ~ 40% increase elsewhere	Work stoppages (OH&S), disruption of transport (road and rail) to ports; increased energy use
Droughts	More common, intense and longer	Greater risk of droughts in mid-continental areas	Water shortages, poor agricultural commodity production

According to Portillo Juan et al. (2022) sea level rise caused by climate change will affect the water depths of Mediterranean ports and inevitably alter wave propagation patterns, which may have repercussions for infrastructure stability. The rise in sea level poses several difficulties for ports, such as coastal erosion, navigation and channel maintenance, infrastructure vulnerability and port resilience and adaptation. For the identification of climate change impacts on coastal zone and port defense structures, Galiatsatou et al. (2021) developed a methodological framework based on nonstationary extreme value analysis of nearshore sea-state parameters. In Greece, they find that total water level peaks and that the northern Aegean Sea will experience an increase in extreme southerly winds after 2060. They also state that when there are observed excessive wave height within the port/harbor basin under normal weather conditions, it leads to port outage (Serviceability Limit State) without catastrophic collapse of defense structures. To address the challenges following a sea level rise, ports need to pursue measures on climate change adaptation.

Several empirical studies have tried to understand and present both the effects of climate change on ports and the state-of-the-art technologies for ports' climate change adaptation. Internet of things (IoT) with blockchain technology seems to be one of the dominant areas in the operations of the ports (Alahmadi et al., 2021; Ayub Khan et al., 2022; Cil et al., 2022; Heikkilä et al., 2022). This digital connection establishes intelligent node-to-node communication with various service automation that reduces human costs. The wireless sensors network is used to handle and manage all operational controls and coordinate various activities, such as dynamic monitoring, real-time monitoring, remote system diagnostics, and dynamic control of production systems. The blockchain technology on the other hand enables stakeholders to verify and validate, store, and synchronize the contents of duplicated information in a secure and protected format among connected parties. A system that integrates the capabilities of IoT and blockchain is capable of running simulations and analyzing current and future alternatives in order to provide real-time recommendations for the most viable and optimal manufacturing process, thereby minimizing wasteful outcomes.

In terms of infrastructure, coastal zone management entails in-depth vulnerability assessments in order to comprehend the threats posed by sea-level rise, storm surges, and coastal erosion and the development of adaptation plans based on these assessments, which may include shore nourishment, the construction of protective barriers such as sea walls or breakwaters, or the implementation of managed retreat strategies. Budget planning is an essential aspect of administering ports efficiently and effectively. Planning a port's budget requires a number of essential components, including revenue projections, operating expenses, capital expenditures, maintenance and enhancements, financial analysis, and stakeholder participation. By taking into account factors such as trade volumes and market conditions, port authorities can accurately project their revenue streams. Expenses associated with personnel, maintenance, security, utilities, and administrative functions are included in operating expenses.

Ports allocate funds for ongoing maintenance, repairs, and enhancements to guarantee optimal functionality and safety. Depending on the port's expansion intentions, a portion of the budget may be allocated to infrastructure development. This may require the construction or expansion of additional berths, terminals, warehouses, or road/rail connections. Last but not least, stakeholder engagement ensures that the budget planning process is aligned with the needs and priorities of shipping lines, terminal operators, labor unions, government agencies, and local communities.

Adaptation to climate change necessitates the participation of multiple stakeholders in cooperative efforts. Ports should collaborate with government agencies, local communities, enterprises, and environmental groups to develop and implement effective adaptation strategies. This collaboration may involve the exchange of data and expertise, the conduct of collaborative risk assessments, and the development of coordinated plans that take into account the requirements and concerns of all stakeholders. Climate change adaptation can be broken down into a number of elements that affect ports' administration preferences.

Preferences for climate change adaptation and mitigation technologies are disclosed when a trade-off or selection among various alternatives occurs. Decision-making processes can be characterised by diverse economic and psychological frameworks, ranging from neoclassical rational choice theories to cognitive models grounded in inductive search heuristics (Devetag, 1999). No singular model is universally applicable; its suitability is contingent upon the intended aim of utilisation. Random Utility Theory (RUT) is particularly enlightening for our objectives (Baltas & Doyle, 2001; Batsell & Louviere, 1991). RUT can include most of these theories within a realistic choice framework.

Choice models often posit that agents obtain value from the characteristics of options under a certain decision context (e.g., a choice task). In each task, agents select the option with the greatest utility. RUT shares this assumption but considers the heterogeneity of individual agents and the circumstances of the decision. In RUT, utility (U) is a latent construct comprising a deterministic component (V) and an error component (ε). The utility of alternative j for individual i is expressed as follows:

Equation 1 – Utility function of individual I from alternative j

$$U_{ji} = V_{ji} + \varepsilon_{ji}$$

The value of Vij is ascertained by a collection of observed attributes linked to alternative j or agent i. Each attribute is assigned a weight denoted by the coefficient βij. The error component εij is influenced by factors like unobserved qualities, agent characteristics, measurement error, functional misspecification, and restricted rationality. Ultimately, it encapsulates the variety among citizens about their decision-making behaviour (Vermunt JK & Magidson J., 2002). In summary, εij imparts probabilistic characteristics to the decision model.

Scientists generally favour grounding their analyses in revealed preferences, which are inferred from the observed actions of economic agents. This method is suitable for assessing market and community acceptability, but it cannot assess socio-political acceptance due to the unavailability of revealed preference data prior to market launch. An alternative is to utilise self-reported preferences of data agents. These are termed stated preferences and can be quantified through ordinal ratings, rankings, or contingent valuation. These techniques possess inherent drawbacks. Research indicates that agents often find it challenging to articulate their preferences effectively in situations involving complex trade-offs, particularly when they possess only limited personal experience with the alternatives (Ben-Akiva et al., 1992; Beshears et al., 2008).

Evaluating and prioritising the technological solutions that can support the climate change adaptation and mitigation needs of the ports is not an easy task. This includes, among other things, a realistic representation of the good under valuation, clarity in the content of the attributes in terms of meaning and measurement, and a market-based simulation that does not impose a cognitive burden on the respondent (Hensher et al., 2015). The Discrete Choice Experiment is a more reliable method (Batsell & Louviere, 1991; Davidson & Farquhar, 1976; Hensher et al., 2015). In a DCE, participants are presented with a sequence of choice tasks, typically formatted as a questionnaire. Each activity presents two or more possibilities from which responders must select. Alternatives vary based on a fixed set of criteria. It is standard practice to use numerous questionnaires featuring systematically varied attribute levels and choice tasks in the experimental design. This can significantly enhance both the volume and calibre of data acquired via the questionnaire.

Several Discrete Choice Experiments (DCEs) have been undertaken to assess preferences for green energy technologies, as well as circularity, air and water quality, concentrating on adoption behaviour and market acceptance. The quantity of DCEs has surged significantly in recent years for public approval, as evidenced by references (Bennett et al., 2016; Fischbacher et al., 2015; Lei et al., 2023; Newell & Siikamki, 2015; Raviv et al., 2021; Vecchiato & Tempesta, 2015). These studies examine the consumer's readiness to pay for alternative energy sources, air-quality improvement policies or recycled water. Nonetheless, no research has yet established how targeted information and prior training influence the acceptance of specific innovative technologies across the ports' managers. Additionally, this research will contribute knowledge regarding ports' and marina's preferences for climate change adaptation and mitigation.

3. Case study

The challenges facing the global shipping and port industry in terms of its energy transition and contribution to global climate neutrality goals are enormous. Research, technological development and innovation will play a catalytic role in addressing them and maintaining the competitiveness of those involved in this transition. However, there is a global weakness in the sector's businesses in terms of easy connection to the innovation ecosystem, as well as a lack of information and awareness on issues related to sustainable development and climate change. Furthermore, developments in the relevant regulatory framework are so rapid that businesses cannot keep up with this pace on their own.

In this context, the MENA Maritime Accelerator[1] offers selected start-ups training through a series of targeted seminars, guidance with experienced mentors, assessment of the technology level of their solution (TRL), and support through financing and networking with the industry. In 2023, 13 start-ups were selected in the MENA Accelerator programme offering innovative solutions in alternative propulsion systems, environmental measurement, monitoring and control, alternative energy, business models and low carbon logistics. On the other hand, the programme helps participating companies (problem owners) in the industry with investment opportunities, technological solutions and increased connectivity with the

[1] http://maritime-accelerator.org

research and development sector. In addition to the seminars offered to the start-ups as part of their program access, a series of seminars (refer to Table 3), adapted and targeted to the needs of port infrastructures, were designed and implemented in 2023 targeting Greek port authorities, municipal port funds, and marina management companies. The aim of these seminars was to connect issue owners with solutions (start-ups) and facilitate their active engagement. To enhance the matchmaking between start-ups and participating companies, a matchmaking event was held for both parties to collaboratively share their ideas and difficulties.

The seminars aimed to provide stakeholders with the knowledge and motivation necessary for active involvement in climate change mitigation and adaptation, ensuring local port development aligns with national and EU sustainability objectives. The first seminar aimed at improving the understanding of blue growth and sustainable port development, encompassing the function of ports in the sustainable blue economy and ecologically responsible maritime practices. The second introduced clean energy and energy conservation strategies, advocating for the adoption of renewable energy technology, energy efficiency initiatives, and the establishment of energy communities in port settings; while the third clarified the changing institutional and regulatory framework, particularly on sustainability and circular economy requirements pertinent to commercial and tourist ports.Finally, the last webinar emphasized digital technologies, ESG (Environmental, Social, Governance) standards, and corporate sustainability strategies to ensure the resilience of port operations.

This study aims to assess the contribution of the seminars to the understanding of the basic principles of sustainable development, as well as to collect your preferences and opinions on various solutions for climate change adaptation/mitigation. There are many innovative solutions to strengthen a port's position in the face of climate change. In this study, we have collected the solutions emerging from the MENA Maritime Accelerator and grouped the most relevant ones into the following five (5) areas of action to support port mitigation and adaptation efforts, namely, circular economy, clean energy production and storage, water quality and air quality.

4. Experimental Design

This research utilises a pairwise comparison methodology inside a discrete choice experiment (DCE) framework to assess individual stated preferences for various climate-related advances. This technique is frequently used in the economic valuation of goods and services. A hypothetical trade-off is created through a survey-based study in order to estimate the benefits of upskilling (Hensher et al., 2015). The ability to forecast future choice responses by eliciting preferences of individuals regarding a good under hypothetical conditions is one advantage of using a DCE. The options provided to respondents encompass several technological solutions (e.g., circular economy solutions, air and water filtering technologies and renewable energy generation and storage), each characterised as a unique characteristic level.

The employed attributes and their levels are presented in Table 4. The solutions presented span key sustainability themes in ports, including circularity, clean energy, water and air quality. Circularity innovations include plastic extraction from marine waste and reusable modular packaging. Clean energy and emissions technologies range from swappable battery networks and floating solar systems to advanced site selection tools, microplastic filtration, underwater inspection, real-time port emissions tracking, and compact exhaust gas filters cutting up to 99% of pollutants.

The economic experiment consisted of three tasks and an eligibility question, as the target group for this survey[2] was port managers in Greece who participated in the MENA Accelerator seminars. The second and fourth parts aimed at collecting data on respondents' experience from the seminars (see Table 3), as well as demographic data on respondents' gender, age, education level, income, number of children, and work experience. The third and main task consisted of a paired comparison exercise, where subjects were asked to make choices between technological solutions with different characteristics. The uniqueness of this study lies in the levels of the paired comparison task, which represent the new solutions.

Participants were presented with a series of binary choice tasks (i.e., each task consists of two alternatives) and asked to indicate which of the two options they would prefer. Each pairwise comparison constitutes a single choice set, and each respondent completed multiple such sets. The experimental design ensures orthogonality and balance across attribute levels to minimize correlation between attributes and maintain statistical efficiency. A randomized design was used to allocate choice sets to respondents, and the position of the alternatives (left/right) was also randomized to reduce ordering effects.

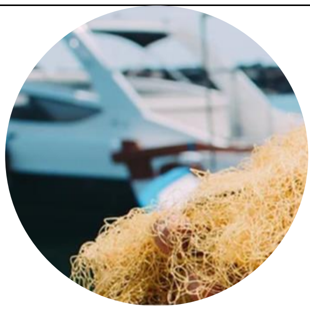
Table 3 - Definitions of the MENA Accelerator seminars

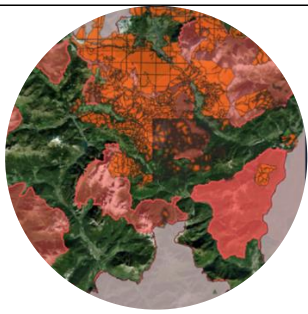
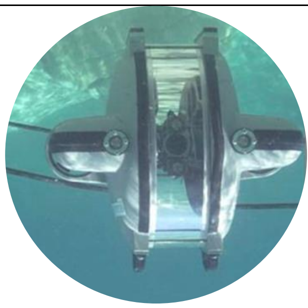
Variable	Seminar	Date and Location	Variable	Thematic Presentation
ASEM1	Seminar on Blue Growth, Sustainable Shipping & Ports	26.05.2023 (online)	**A2SEM1a**	"Adequate, safe, accessible and well-maintained ports: A primary condition for Blue Growth"
			A2SEM1b	"Reducing greenhouse gas emissions in shipping: Actions in the International Maritime Organization (IMO) and the European Union"
ASEM2	Seminar on Green Energy, Energy Saving, Energy Communities	29.06.2023 (online)	**A2SEM2a**	"The Institution of Energy Communities - European and National Framework"
			A2SEM2b	"The role of ports in the decarbonization of shipping, and the path to zero emissions during the stay of ships in port"
			A2SEM2c	"Small Winds. autonomy and electromobility systems of domestic added value for the country's ports"
ASEM3	Seminar on the Institutional framework for sustainability and circular economy in commercial and tourist ports.	28.09.2023 (online)	**A2SEM3a**	"About ports, the European and International regulatory framework towards a sustainable transition"
			A2SEM3b	"Transforming Ports: Circular Economy and Sustainability"
			A2SEM3c	"Requirements and improvements against aviation, strategic environmental assessment and

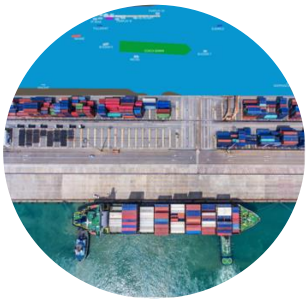
[2] https://forms.gle/JzYb7c6nMvH7Rt518

				environmental licensing of commercial and tourist ports"
ASEM4	Seminar on Digital Transition, Corporate Sustainability Criteria and Sustainable Transformations	26.10.2023 (online)	**A2SEM4a**	"Sustainable Digital Transition in the port industry"
			A2SEM4b	"Environment, Society and Corporate Governance (ESG): Critical areas that determine the future financial performance of companies - The case of ports"
			A2SEM4c	"ESG Dashboard and Case Study of a Greek Port"
ASEM0	None	n/a	n/a	n/a

Table 4 – Definitions of the innovations used when conducting the pairwise comparisons.

Attributes		**Description**		
CIRCULARITY	CIRC1	 © Reelease	A recycling technology that will extract plastic from mooring ropes, ghost nets and other marine waste	A recycling or even repurposing effort targeted around the main materials used in their manufacturing aiming to reduce the pollution and disruption caused by their harmful disposal. This technology focuses specifically on extracting plastic from mooring ropes, ghost nets and other marine waste
	CIRC2	 © Ponera Group	A smart, reusable and durable modular packaging system	A smart modular packaging system which by their assembly, can provide any sizes in terms of surface area. It replaces conventional packaging and crates used once with a reusable and durable solution.
CLEAN ENERGY	NRG_storage1	 © Rhoé	A swappable battery network that provides clean energy at a competitive price	It offers vessel owners and operators a swappable battery network that provides clean energy at a competitive price, without the need for high capital investment.

	NRG_storage2	 © ENEXAN	A hardware solution that will expand EV Charging to multiple locations from the same Fast-Charger	An innovative hardware solution, that can expand EV Charging to multiple locations from the same Fast-Charger. This modular, low-cost system allows Fast-Chargers to increase their utilization rate 3x-5x times under the same traffic conditions
	NRG_production1	 © Enernite	An advanced analysis (using satellite imagery data) for a rapid early-phase site selection of a renewable energy project.	It utilizes advanced analysis of satellite imagery and automated information gathering from fragmented sources to enable rapid, data-driven decisions. With in-depth information and updated data of various geographical locations, it enables better overview and automated on-demand site assessments of selected factors, such as economy, ecology, grid-network, road-network and more.
	NRG_production2	 © HelioRec	A floating solar technology to generate clean energy	Generation of clean electricity from a cutting-edge floating solar technology.
WATER QUALITY	WATER1	 © MicroPlastic	A filtration equipment to collect microplastics in a port	A non-consumable filtration equipment to collect microplastics (collect >20 µm) in river/harbour and particles in wastewater factory. The equipment has the advantages of no consumable, low cost, and low energy consumption.
	WATER2	 © NavHome	A tool that does underwater asset inspection	It uses an innovated acoustic navigation system designed to provide navigational data. It integrates global satellite navigation, a variety of payload, ultra-sonic sensors, sonars and manipulators. It has sensors that can be deployed close to the seafloor and produce hydrographic and geophysical survey data of the highest quality and optimum resolution.

AIR QUALITY	AIR1	 © Navisense	System that will calculate port air emissions and monitor a ship's position, speed, and course, which can help optimize portcalls	An innovative solution to estimate all emissions within a port or surrounding area in near real-time and using High-frequency AIS (Automatic Identification System) data it will provide real-time information about a ship's position, speed, and course, which can help optimize portcalls. With this data, port operators can monitor the progress of a ship's journey to the port, anticipate its arrival time, and prepare for its arrival. Once the ship is in port, AIS data can also be used to track the progress of the portcall, such as when cargo is loaded and unloaded, and when the ship departs.
	AIR2	 © Solumar	A filtering technology that captures GHG emissions.	It is a novel Exhaust gas filtering technology that cuts 92-99% of all emissions (PM, VOCs, GHG) combined, with a single compact unit, retrofittable to any emitting source, no matter the size, type, and nominal airflow.

5. Model and Estimation

To analyze discrete choice behavior across alternatives characterized by categorical attributes, we estimate a conditional logit model following the framework of (McFadden, 1974). The model is appropriate when choices are made from sets of mutually exclusive alternatives, and each alternative is described by a vector of attributes. In this context, we consider a set of alternatives $j \in C_t$ within each choice set or "card" t, where the dependent variable Y_{jt} equals 1 if alternative j is chosen and 0 otherwise.

Let x_{jt} denote the vector of attributes describing alternative j in card t. Then the utility U_{jt} that individual i derives from alternative j in card t is modelled as:

Equation 2 – Utility function of individual i from alternative j in card t

$$U_{jt} = x_{jt}\beta + \varepsilon_{jt}$$

Where x_{jt} is a vector of observed attributes (dummy-coded for each level), β is the vector of coefficients to be estimated, and ε_{jt} is an idiosyncratic error term assumed to follow an extreme value type I distribution (Gumbel). Under these assumptions, the probability that alternative j is chosen from choice set t is:

Equation 3 – Choice probability

$$P\left(Y_{jt} = 1 \,\middle|\, C_t\right) = \frac{\exp(x_{jt}\beta)}{\sum_{k \epsilon C_t} \exp(x_{kt}\beta)}$$

This is the conditional logit likelihood. The model is estimated using maximum likelihood, conditioning on the choice set. This specification ensures that the estimation respects the structure of the data—namely, that each decision-maker chooses exactly one option per card. The exponentiated coefficients $\exp(\beta_j)$ from the model correspond to odds ratios—the relative odds of an alternative with attribute j being chosen versus the reference category, controlling for the choice set.

To further develop the discrete choice analysis and investigate variability in selection behaviour, a classification tree model was utilised employing the CART (Classification and Regression Trees) algorithm, executed through the rpart package in R. This non-parametric approach was selected to model the probability of an alternative being chosen (i.e., Chosen = 1) based on both alternative-level attributes (e.g., technology type – see Table 4) and respondent-specific characteristics, including gender, age, education, income, number of children, and years of experience; and attendance at the MENA Maritime Accelerator seminars (see Table 3). In contrast to conventional econometric models that enforce linearity and additivity assumptions (such as conditional logit or multinomial logit), the classification tree methodology provides a flexible, data-driven framework that reveals intricate interactions and non-linear effects without the need for pre-defined functional forms.

The classification tree is constructed through recursive binary partitioning of the dataset. At each node, the algorithm selects the predictor and corresponding split point that result in the greatest reduction in node impurity, which is quantified using the Gini index. The Gini index at node t is defined as:

Equation 4 – Gini index

$$G(t) = \sum_{i=1}^{C} p_i(t)\big(1 - p_i(t)\big) = 1 - \sum_{i=1}^{C} p_i(t)^2$$

where C is the number of classes (here, 2: Chosen = 0 or 1) and $p_i(t)$ is the proportion of observations of class i in node t. The Gini index measures the level of impurity: it reaches its minimum value (0) when all observations in the node belong to a single class, and its maximum when the classes are perfectly mixed. At each split, the algorithm chooses the variable and threshold that minimise the weighted sum of Gini impurity in the resulting child nodes, thereby producing increasingly homogeneous subgroups.

Upon completion of the tree's construction, each terminal (leaf) node represents a predicted class label together with its corresponding class probability. The forecast for a new observation relies on the trajectory it traverses through the tree, dictated by the values of its predictor variables, until it arrives at a terminal node. The anticipated class is the one with the greatest proportion of observations within that terminal node. Mathematically, the predicted probability that a new observation x is assigned to class 1 is:

Equation 5 - Predicted Probability

$$\widehat{\mathrm{P}}(\mathrm{Y} = \mathrm{i} \mid X) = \frac{1}{N^t} \sum_{j \epsilon R_t} 1(y_i = i)$$

where R_t denotes the set of training observations that fall into terminal node t, and $N_t = |R_t|$ is the number of such observations. The indicator function $1(y_i = i)$ equals 1 if the j-th observation belongs to class i, and 0 otherwise. This formulation means that the classification tree estimates the conditional class probabilities by calculating the relative frequency of each class in the terminal node to which x is assigned. This modelling approach facilitates clear interpretation via simple if–then principles and uncovers essential interaction patterns that might be concealed in parametric models. The resulting tree was pruned to optimise explanatory power and model simplicity, reducing overfitting while maintaining interpretative clarity.

6. Data collection and results

This research employed an online survey created with Google Forms to evaluate the viewpoints of Greek port authorities, municipal port funds, and marina management companies concerning climate change mitigation and adaptation measures. First, participants were briefed on the study's aims, anticipated duration (15–20 minutes), and data confidentiality protocols. An informed consent was secured by a mandatory agreement checkbox prior to continuing. All responses were kept anonymous and securely stored within the ATHENA Research Center's network. Participants were informed that they could exit the survey at any time simply by closing the browser window.

The first part of the survey conducted an assessment of the MENA Maritime Accelerator Seminars, where respondents were requested to provide feedback on their participation and experiences, concentrating on the seminars' success in improving comprehension of sustainable development concepts related to the shipping and ports industries. During the pairwise comparison task, participants encountered a sequence of binary choice situations, each showcasing two distinct solutions related to climate issues. Solutions were grouped into five areas: circular economy, clean energy production, energy storage, air quality, and water quality. Respondents chose the solution they considered more impactful for addressing climate change in relation to port operations. Finally, the last part aimed at gathering information regarding participants' gender, age, education level, income, number of children, and work experience.

6.1. Descriptive statistics of the sample

In total, the survey was filled in by 16 port managers, leading to 1335 observations. The study's target group was confined, which explains the sheer number of responses. Table 5 presents the descriptive statistics for the total sample. Compared to the Greek national population (Hellenic Statistical Authority, 2022), the study sample comprised more females (0.75 versus 0.51) and consequently fewer males (0.25 versus 0.48). The average age of the respondents is 44 years with a standard deviation of 6.79 years, which indicates that there is a wide age range and it is also close to the national average of 40.6. They also have an average of 20.25 years of education, which indicates that the respondents are well educated having pursued on average a university degree. This average is almost double than the national average of 10.9 years of education.

In terms of work experience, the participants have an average of 8.6 years of work experience, with a rather high standard deviation of 8.77 years. This indicates that there is a mix of participants who have both a little and a significant amount of work experience. The mean reported monthly income is €3,218, exhibiting significant variability (SD = €1,934). This indicates a comparatively wealthy demographic characterised by significant income variability. Finally, respondents indicated an average of 0.5 children, suggesting that a significant proportion are either childless or have small households. In general, the sample is not completely representative of the Greek population. This can be due also to the fact that respondents were recruited not from Greece at large, but from key positions in the port authorities in Greece, which may explain different structures in terms of socio-demographics related characteristics compared to the national average. Thus, some caution should be used in generalizing the study's results to the entire country.

Table 5 - Descriptive statistics for the sample (n=16). Sample mean (standard deviation in parentheses)

Characteristics	**Mean (SD)**
Gender (Female =1)	0.75 (0.45)
Age (years)	44 (6.79)
Education (years)	20.25 (4.12)
Income (euros)	3,218 (1,934)
Number of Children	0.5 (0.5)
Work experience (years)	8.6 (8.77)

6.2. Seminars' evaluation

The initial segment of the survey sought to delineate respondents' involvement in the MENA seminars, assessing their experiences and the impact of these seminars on their understanding of climate change mitigation and adaptation strategies. Participants were requested to select the webinars they watched and to indicate their satisfaction with the instructional content using a Likert scale from 1 to 5, where 1 signifies "not at all" and 5 signifies "very much" (see the thematic seminars and presentations at Table 3 - Definitions of the MENA Accelerator seminarsTable 3). As we see in Table 6 and Figure 1, the majority of the respondents participated in all four webinars, and their evaluations were predominantly positive, with the lowest mean score of 4 for the presentation on the circular economy (A2SEM3b); and the highest mean score of 4.7 and standard deviation of 0.48 for the ESG dashboard concerning Greek ports, implying strong consensus about its usefulness and clarity. The presentation on the role of ports in the decarbonization of shipping, and the path to zero emissions during the stay of ships in port (A2SEM2b) was highly appreciated, with very low SD, indicating uniformly positive evaluations. While the presentation on the circular economy (A2SEM3b) was the lowest-rated session, it still received a positive rating, with a high standard deviation (SD) indicating divergence in views, as some participants may have found it less clear or relevant.

Table 6 – Participation in the MENA Accelerator Seminars' evaluation (n=16). Sample mean (standard deviation in parentheses)

Variables	Description	Mean Attendance (SD)
ASEM1	Seminar on Blue Growth, Sustainable Shipping & Ports	0.69 (0.48)
ASEM2	Seminar on Green Energy, Energy Saving, Energy Communities	0.63 (0.5)
ASEM3	Seminar on the Institutional framework for sustainability and circular economy in commercial and tourist ports.	0.68 (0.48)
ASEM4	Seminar on Digital Transition, Corporate Sustainability Criteria and Sustainable Transformations	0.56 (0.51)
ASEM0	None	0.12 (0.34)

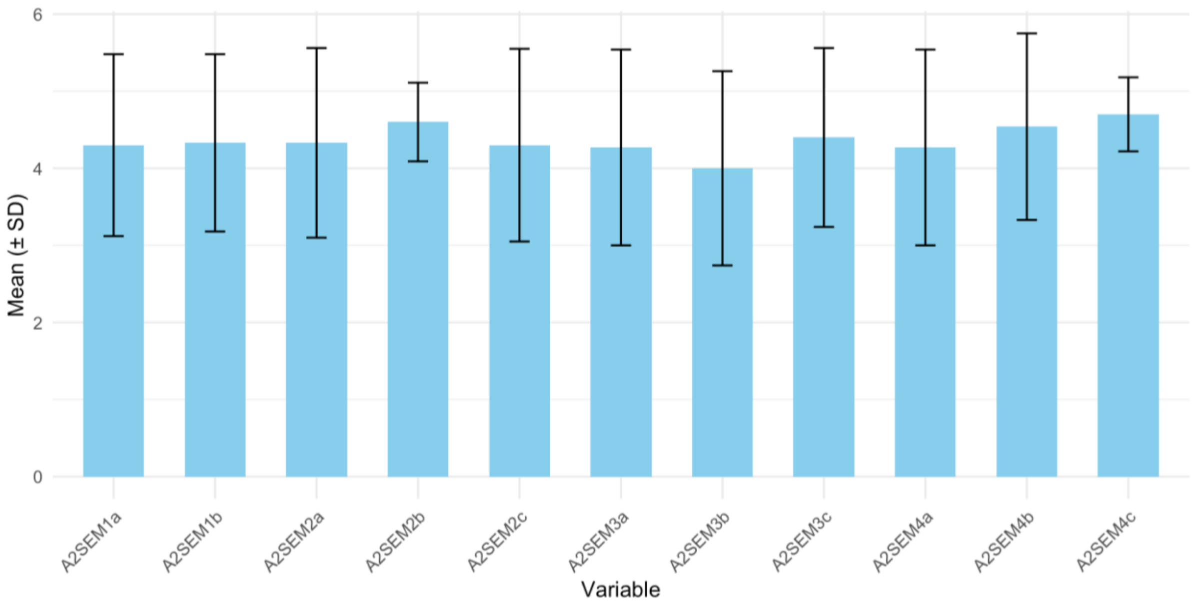


Figure 1 - Seminars' satisfaction (Means and Standard Deviations of Lectures within the seminars)

Participants were also asked to evaluate their level of knowledge regarding sustainability concepts, using a Likert scale from 1 to 5, where 1 represents "limited knowledge", and 5 represents "extensive knowledge". Using paired comparison, we see that the mean understanding of sustainability topics before participating in the MENA seminars (A3PRIOR) was 3.2 (1.26), and post-seminar (A4POST) it was 3.9 (0.96), with a p-value of 0.04, indicating statistical significance in the score changes at a 95 percent confidence interval. This implies that we can confidently attribute the observed change in participating to the MENA seminars rather than random variation.

Table 7 - The difference between post- and prior-knowledge on sustainability matters, before and after participating in the MENA Accelerator seminars

VARIABLES	MEAN (SD)
A4POST – A3PRIOR	0.73 (1.28)
KNOWLEDGE ON SUSTAINABILITY MATTERS (BEFORE) – A3PRIOR	3.2 (1.26)
KNOWLEDGE ON SUSTAINABILITY MATTERS (AFTER) – A4POST	3.9 (0.96)

P-VALUE	0.04

The results depicted in Figure 2 show the self-reported origins of knowledge regarding climate change mitigation and adaptation, derived from binary replies (e.g., yes = 1, no = 0). Each source is accompanied by its mean (percent of participants selecting it) and standard deviation. As we see, respondents seem to prefer websites, news and media, as well as seminars, to get informed on these topics, rather their individual experiences and their university degrees.

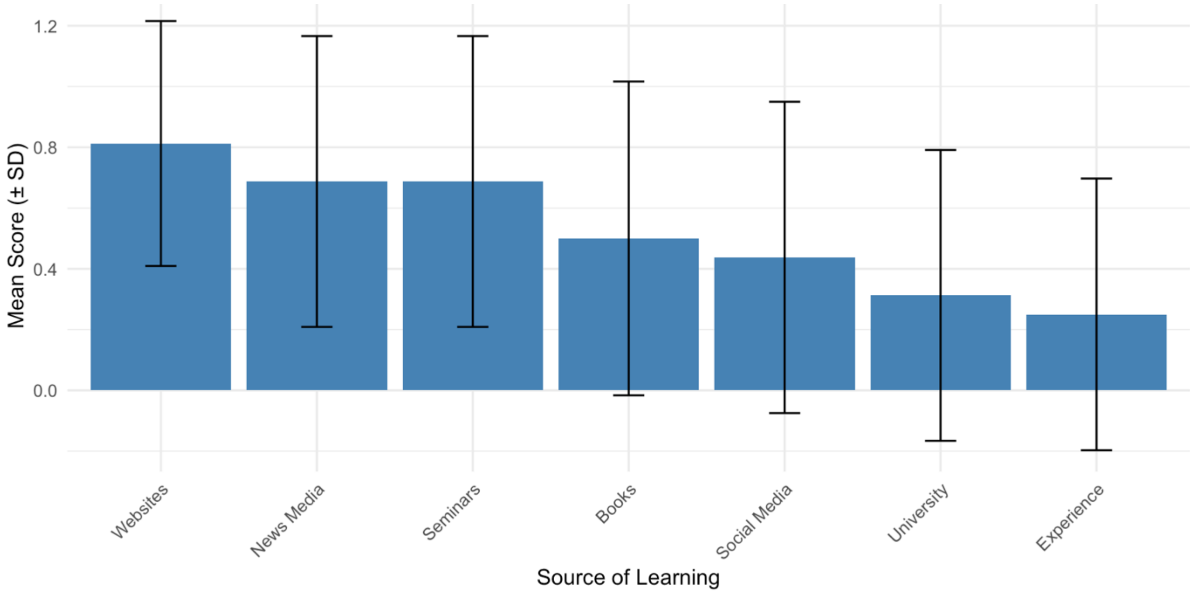


Figure 2 - Perceived Sources of Learning on Climate Change Adaptation and Mitigation

6.3. Paired Comparison rankings and choice probabilities

We employed a conditional logit model to assess participant preferences for various technological solutions based on pairwise comparison data. The dependent variable was a binary indication denoting the selection of a specific technology over an alternative within a designated pair. The principal predictor was a categorical variable differentiating the ten technical options assessed. Interaction terms were incorporated to explain the impact of respondent variables (e.g., income level, education, and seminar attendance) on technology selection. Furthermore, we accounted for the sequence of presentation and task number, mitigating possible fatigue or positional effects. Before analysing the final model, we evaluated the presence of heterogeneity among respondents, recognising that people may demonstrate differing degrees of decision consistency.

The ranking of technological solutions by total votes indicates a distinct preference for energy-related innovations, especially in production and air quality (refer to Table 1). NRG_PRODUCTION2 leads with 89 votes, demonstrating robust support for innovative energy generating solutions, while AIR2 follows closely with 82 votes, indicating significant appreciation for air-related innovations. Storage systems such as NRG_STORAGE2 and NRG_STORAGE1 are ranked third and fifth, respectively, underscoring the significance of effective energy management. Significantly, first-generation solutions like

NRG_PRODUCTION1 and AIR1 garnered fewer votes than their second-generation equivalents, indicating a desire for more sophisticated or enhanced technology. Water-related technologies (WATER1 and WATER2) rank in the mid to lower tiers, indicating modest interest, but circular economy innovations (CIRC1 and CIRC2) garnered the least votes, signifying they are presently deprioritized by voters. The data predominantly emphasises energy and air solutions, particularly recent innovations, while placing comparatively less importance on water and circularity.

Table 8 - Ranking of all Technological Solutions

TECHNOLOGICAL SOLUTION	TOTAL VOTES	RANK
NRG_PRODUCTION2	89	1
AIR2	82	2
NRG_STORAGE2	72	3
AIR1	69	4
NRG_STORAGE1	60	5
WATER1	58	6
NRG_PRODUCTION1	55	7
WATER2	42	8
CIRC1	31	9
CIRC2	22	10

Table 9 presents the predicted choice probabilities, calculated using Equation 3. The dominant preference shares of the alternatives NRG_production2, NRG_storage2,, and AIR1/2 are clear in this table, as they have the highest predicted choice probabilities, reflecting their high utility scores in the conditional logit model. Nevertheless, the alternatives CIRC1 and CIRC2 consistently exhibit low predicted probabilities (between 0.0068 and 0.0109 and 0.0037 and 0.0059,, respectively), even when actually chosen, underscoring their limited appeal across respondents. The model attributes moderate probabilities to the rest of the alternatives,, indicating these options possess limited projected utility; however, they may be selected occasionally due to unobserved heterogeneity or particular respondent preferences not accounted for in the model.

Table 9 - Predicted choice probabilities for a single card that includes all 9 options

Chosen Alternative/Reference category	CIRC1	CIRC2	AIR1	AIR2	NRG_production1	NRG_production2	NRG_storage1	NRG_storage2	WATER1	WATER2
CIRC1	0.0068	0.0068	0.0075	0.0082	0.0071	0.0109	0.0073	0.0078	0.0070	0.0069
CIRC2	0.0037	0.0037	0.0041	0.0044	0.0038	0.0059	0.0039	0.0042	0.0038	0.0038
AIR1	0.1034	0.1031	0.1145	0.1245	0.1082	0.1659	0.1108	0.1193	0.1072	0.1056
AIR2	0.1762	0.1756	0,1950	0.2121	0.1843	0.2825	0,1888	0.2032	0.1826	0.1799
NRG_production1	0.0506	0.0504	0.0560	0.0609	0.0529	0.0811	0.0542	0.0583	0.0524	0.0517
NRG_production2	0.3832	0.3820	0.4242	0.4613	0.4007	0.6145	0.4106	0.4419	0.3972	0.3914
NRG_storage1	0.0735	0.0733	0.0814	0.0885	0.0769	0.1179	0.0788	0.0848	0.0762	0.0751

NRG_storage2	0.1397	0.1392	0.1546	0.1681	0.1461	0.2239	0.1496	0.1611	0.1448	0.1426
WATER1	0.0421	0.0420	0.0466	0.0507	0.0440	0.0675	0.0451	0.0486	0.0436	0.0430
WATER2	0.0277	0.0276	0.0306	0.0333	0.0289	0.0444	0.0296	0.0319	0.0287	0.0283

6.2. Tree Models

Two classification trees have been developed aiming to identify the relationship between specific subgroups within the dataset and participants' preferences. The first tree model investigates the impact of respondents' demographic characteristics and their inclinations towards sustainable solutions. Figure 3 illustrates that the circular solutions (CIRC1/2) exhibit a markedly low selection rate of 21% and are unaffected by demographic variables. Nonetheless, educational background and financial level seem to influence respondents' decisions. Possessing a minimum of a high school diploma significantly increases the likelihood of choosing AIR2 and NRG_production2, with a selection probability of 71%. Achieving a minimum of a high school diploma, along with a minimum monthly disposable household income of 4000 euros, results in a 73% likelihood of selecting NRG_storage1/2 and AIR1. Conversely, respondents with a monthly income below 2000 euros and with a minimum of a high school diploma have an 81% likelihood of selecting solutions pertaining to water quality (WATER 1/2) and energy production (NRG_production1).

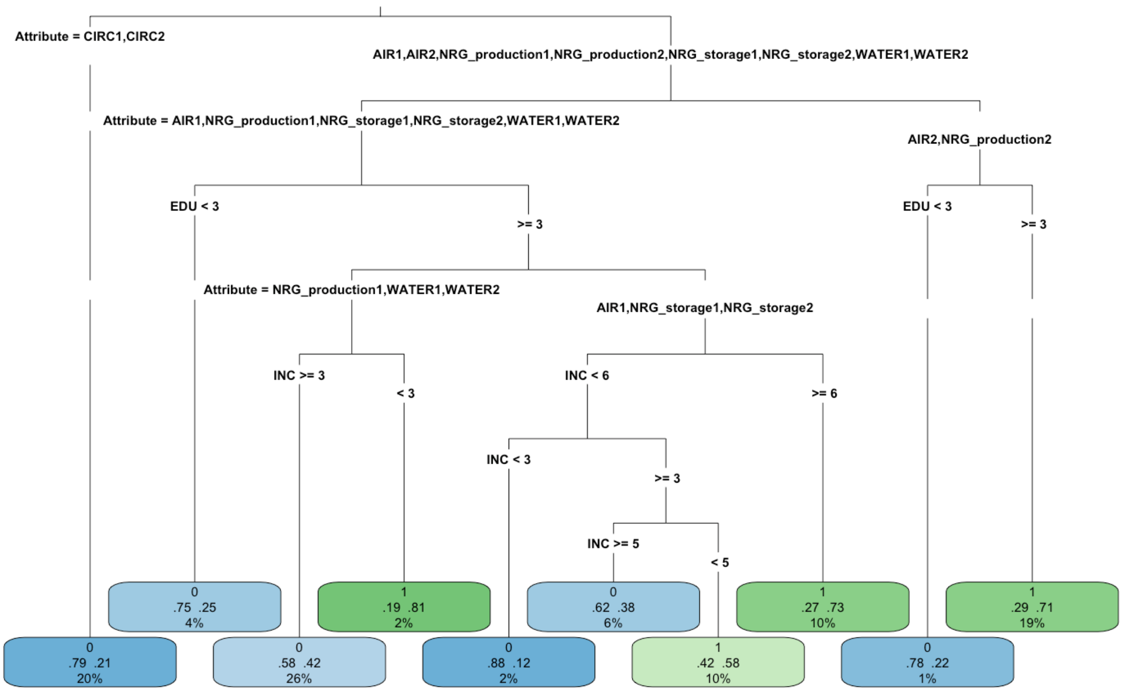


Figure 3 - Tree Model for the "demographics" subgroup

The second classification tree that was constructed sought to simulate the likelihood of a specific alternative being selected (chosen = 1) based on its attribute type (see
Table 3 - Definitions of the MENA Accelerator seminars

Variable	Seminar	Date and Location	Variable	Thematic Presentation
ASEM1	Seminar on Blue Growth, Sustainable Shipping & Ports	26.05.2023 (online)	**A2SEM1a**	“Adequate, safe, accessible and well-maintained ports: A primary condition for Blue Growth”
			A2SEM1b	“Reducing greenhouse gas emissions in shipping: Actions in the International Maritime Organization (IMO) and the European Union”
ASEM2	Seminar on Green Energy, Energy Saving, Energy Communities	29.06.2023 (online)	**A2SEM2a**	“The Institution of Energy Communities - European and National Framework”
			A2SEM2b	"The role of ports in the decarbonization of shipping, and the path to zero emissions during the stay of ships in port”
			A2SEM2c	“Small Winds. autonomy and electromobility systems of domestic added value for the country's ports"
ASEM3	Seminar on the Institutional framework for sustainability and circular economy in commercial and tourist ports.	28.09.2023 (online)	**A2SEM3a**	"About ports, the European and International regulatory framework towards a sustainable transition"
			A2SEM3b	“Transforming Ports: Circular Economy and Sustainability"
			A2SEM3c	"Requirements and improvements against aviation, strategic environmental assessment and environmental licensing of commercial and tourist ports"
ASEM4	Seminar on Digital Transition, Corporate Sustainability Criteria and Sustainable Transformations	26.10.2023 (online)	**A2SEM4a**	"Sustainable Digital Transition in the port industry"
			A2SEM4b	"Environment, Society and Corporate Governance (ESG): Critical areas that determine the future financial performance of companies - The case of ports"
			A2SEM4c	"ESG Dashboard and Case Study of a Greek Port"
ASEM0	None	n/a	n/a	n/a

Table 4) and topic-specific seminars attended by respondents (see Table 3). The tree (Figure 4) demonstrates significant variability in preferences among attribute categories and subgroups. The first split at the root node is based on the attribute that distinguishes circular economy solutions (CIRC1, CIRC2) from other alternatives. Options CIRC1 and CIRC2 were infrequently selected, with a projected class of 0 (not picked) and merely 21% of respondents choosing them (selection probability), suggesting a comparatively low perceived utility or importance of circular economy solutions relative to other factors in the decision-making environment.

The rest of the tree model differentiates between two primary branches among the remaining parameters. One trajectory leads to water and renewable energy production alternatives (WATER1, WATER2, NRG_production1), wherein the anticipated classification remains predominantly 0 (not selected). The selection probability and projected class of the rest of the variables (NRG_storage1, NRG_storage2, AIR1) are affected significantly by the 1st and 3rd seminars (ASEM1 and ASEM3 respectively). Respondents who followed the third seminar on circular economy seem to not put significant emphasis on solutions for air quality and energy storage, with these alternatives having a 24% likelihood of being selected. However, these solutions seem to be selected by the majority (61%) who attended the first seminar on sustainability challenges that the shipping and ports industries face today and those who didn't follow any of these two seminars (62%).

The projected class for the *floating solar technology that generates clean energy* (NRG_production2) and the *filtering technology that captures GHG emissions* (AIR2) seem to have a projected class of 1, irrespective of the other criteria, in this case, the seminars that respondents attended, with a 67% selection probability.

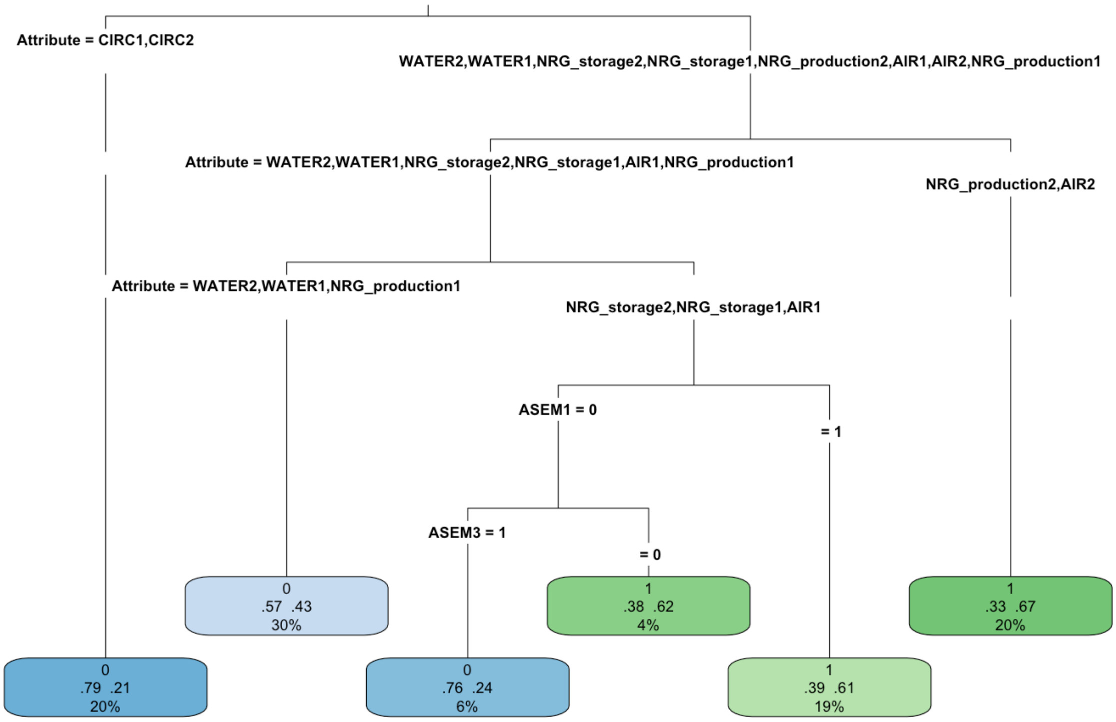


Figure 4 - Tree Model for the "participation in seminars" subgroup

7. Discussion

Our results indicate that more sophisticated and well-branded energy solutions (e.g., NRG_production2, AIR2) garner greater preference signals compared to simpler circular economy options. They resonate with those of Van Rijnsoever et al. (2015) who investigate public acceptance of diverse energy technologies through discrete choice experiments. The study indicates that renewable and natural gas technologies garner greater support when explicitly labelled, whereas lesser-known alternatives such as biomass and nuclear exhibit diminished attraction. In addition, Lei et al. (2023) examine public preferences for air quality enhancement policies, revealing robust support for initiatives focused on diminishing air pollution, especially those pertaining to clean energy and emissions regulation, which is in alignment with the noted high votes for AIR1/2 and the comparatively high predicted probabilities for air-based solutions.

Our conceptualization expands upon that of a recent study focused on the maritime sector that examines stakeholders' preferences for technical (e.g., renewable hardware) compared to operational energy efficiency methods in maritime shipping. The analysis reveals a distinct preference for technical solutions (Longarela-Ares et al., 2023). Our empirical investigation focuses on ports' managers and further enhances our conceptualisation by investigating the significance of these technologies. Our results that next-generation technologies (NRG_production2, AIR2) surpass their predecessors seem to validate the findings of (Longarela-Ares et al., 2023) for the ports sector as well.

When it comes to circular economy, as we see in Figure 3 and Figure 4, circular technologies focused on marine waste recycling (CIRC1) and reusable product design (e.g., packaging – CIRC2) are the least preferred compared with other innovative solutions. (Wiedenhofer et al., 2025) examine comprehensive studies regarding the mitigation potential of the circular economy and find that circular methods yield greenhouse gas benefits; however, their full efficacy is realised only when integrated with energy efficiency and renewable energy. Our data indicating a diminished desire for circular-only innovations (CIRC1/2) unless accompanied by sophisticated energy solutions, corresponds with this overarching conclusion.

Our discussion of ports' manager preferences over the significance and efficacy of suggested technological solutions to support climate change adaptation and mitigation shows that their preferences vary in diverse and often inconsistent ways. While solutions that capture greenhouse gas emissions (AIR2) or generate clean energy (NRG_PRODUCTION2) appear to be favoured by all participants, particularly those with at least a high school diploma, they are outperformed by solutions that calculate port air emissions and monitor a ship's position, speed, and course (AIR1), battery networks that deliver clean energy at a competitive price (NRG_STORAGE1), or hardware that allows a single fast charger to serve multiple electric vehicle charging (NRG_STORAGE2), when the respondent's family income is 4000 euros or greater.

Although discrete choice studies typically emphasise attribute-based modelling, our conceptualisation demonstrates how specific interventions providing targeted information and prior training can substantially affect the prioritisation of attributes by respondents. These results are in line with the findings by earlier studies (Groeneveld, 2010; Van Rijnsoever et al., 2015). In Figure 4, we observe significant alterations in choice probabilities observed in our tree model due to participation in the first and third seminar. Specifically, participants in the third seminar on circular economy appear to place minimal importance on solutions for air quality and energy storage, with these options having a 24% probability of selection. Nonetheless, these solutions appear to be favoured by the majority (61%) of attendees at the first seminar that addressed sustainability concerns in the shipping and ports sectors, as well as by those who did not attend either seminar (62%).

8. Limitations

This study is hindered by several limitations. A key limitation is the restricted sample size of the Discrete Choice Experiment (DCE), which diminishes the statistical power and generalisability of the results. This limitation is mostly due to the restricted reach of the stakeholder group surveyed, which mainly comprised port stakeholders, including port authorities, municipal port funds, and marina operators. Consequently, the responses may inadequately reflect the variety of viewpoints or preferences that would exist in a larger, more diverse group. A second restriction is that our survey was confined to a certain geographical location, rendering our findings inapplicable to the broader European population. A notable possible drawback is to the attributes included in the DCE. These were devised to be representative of the MENA Maritime Accelerator solutions that respondents' were familiar with. The disadvantage is that other innovations with possibly greater interest or impact were not included in the survey. Subsequent study may incorporate more technologies into the choosing task.

9. Conclusions

This study presents definitive empirical evidence of varied preferences for technological improvements in the sustainability sector, as demonstrated by a synthesis of choice modelling and classification tree analysis. Among the assessed options, energy-related technologies—specifically second-generation innovations like floating solar (NRG_PRODUCTION2) and air-filtering systems (AIR2)—consistently ranked as the most preferred, both in total vote counts and anticipated choice probability. Storage solutions (NRG_STORAGE1/2) received a high ranking, underscoring the need of efficient energy management. Conversely, circular economy solutions (CIRC1 and CIRC2) were repeatedly deprioritized, demonstrating the lowest selection rates and forecasted probability, even among participants who attended seminars centred on circularity.

The findings underscore how previous exposure to topic-specific knowledge, such as engagement in seminars, affects technological preferences. General sustainability seminars (ASEM1) were associated with enhanced support for air quality and storage technologies, however circular economy seminars (ASEM3) did not significantly elevate desire for circular solutions. This indicates that the existing communication or instructional framing of circularity may not be effectively engaging with audiences. The results highlight a distinct emphasis on innovations in energy and air quality—particularly more advanced iterations—over water and circular economy technologies, indicating a necessity for more focused engagement strategies to enhance the perceived significance and value of circular solutions within the wider sustainability transition.

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