



**TECHNICAL UNIVERSITY OF CRETE**  
SCHOOL OF CHEMICAL AND  
ENVIRONMENTAL ENGINEERING  
RENEWABLE AND SUSTAINABLE ENERGY  
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***Critical assessment of the sustainable performance of the  
Mediterranean ports***

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*Doctor of Philosophy*

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# PhD Dissertation Committee

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3) Αποδέχομαι ότι το Πολυτεχνείο Κρήτης μπορεί, χωρίς να αλλάξει το περιεχόμενο της εργασίας μου, να τη διαθέσει, μετά το πέρας 24 μηνών από την αρχική υποβολή, σε ηλεκτρονική μορφή μέσα από τη ψηφιακή βιβλιοθήκη του, να την αντιγράψει σε οποιοδήποτε μέσο ή/και σε οποιοδήποτε μορφότυπο καθώς και να κρατά περισσότερα από ένα αντίγραφα για λόγους συντήρησης και ασφάλειας.

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## Περίληψη

Καθώς το τοπίο του παγκόσμιου εμπορίου συνεχίζει να εξελίσσεται, τα λιμάνια όλων των μεγεθών αντιμετωπίζουν όλο και πιο περίπλοκες προκλήσεις στην επιδίωξή τους για βιώσιμη ανάπτυξη. Τα μικρά και μεσαία λιμάνια, αν και συχνά επισκιάζονται από τα μεγαλύτερα ομόλογα τους στη συζήτηση για το διεθνές εμπόριο και τα logistics, διαδραματίζουν σημαντικό ρόλο στις παγκόσμιες αλυσίδες εφοδιασμού και στην περιφερειακή ανάπτυξη. Αυτή η διδακτορική διατριβή παρουσιάζει μια σχολαστική διερεύνηση του βιώσιμου σχεδιασμού των μικρών και μεσαίων λιμένων, αντιμετωπίζοντας την επιτακτική ανάγκη κατανόησης, ενίσχυσης και υποστήριξης για τη βιωσιμότητα και την ανθεκτικότητα αυτών των λιμένων στο παγκόσμιο θαλάσσιο πλαίσιο.

Οι πρωταρχικοί στόχοι αυτής της έρευνας είναι επτά:

1. Παροχή οδηγού για αποτελεσματικό και αποδοτικό σχεδιασμό για τη βιωσιμότητα μικρών/μεσαίων λιμένων
2. Χρήση των εφαρμοζόμενων μεθοδολογιών ως εργαλείων λήψης αποφάσεων με στόχο τη βελτιστοποίηση της βιωσιμότητας.
3. Κατάταξη των προτεραιοτήτων για τη βελτίωση της βιωσιμότητας των λιμένων μέσω των προοπτικών των ενδιαφερομένων
4. Εξέταση του βαθμού ανταπόκρισης/αποδοχής των ενδιαφερομένων/πολιτών στα προτεινόμενα μέτρα βιώσιμης ανάπτυξης
5. Προσδιορισμό των κύριων δεικτών που καλύπτουν τις βασικές κρίσιμες πτυχές των στόχων βιωσιμότητας λιμένων
6. Αξιολόγηση και σύγκριση βιώσιμων δεικτών διαφορετικών λιμένων καθώς και ανταλλαγή βέλτιστων βιώσιμων πρακτικών.
7. Προσδιορισμό και κατηγοριοποίηση απειλών που επικρατούν μεταξύ των συσκευών IoT στις λιμενικές εγκαταστάσεις.

Χρησιμοποιώντας μια προσέγγιση που περιλαμβάνει ποιοτικές και ποσοτικές αναλύσεις, μελέτες περιπτώσεων, συγκρίσεις μεταξύ λιμένων και ενεργό εμπλοκή με τους ενδιαφερόμενους λιμένες, αυτή η διατριβή παρέχει μια ολιστική κατανόηση των πολύπλευρων διαστάσεων που διαμορφώνουν τον βιώσιμο σχεδιασμό σε λιμένες μικρού και μεσαίου μεγέθους. Τα ευρήματα της έρευνας παρέχουν ένα ολοκληρωμένο πλαίσιο για βιώσιμο σχεδιασμό, δίνοντας έμφαση στην

ενσωμάτωση οικονομικών, περιβαλλοντικών και κοινωνικών παραμέτρων και διευκολύνοντας την ευθυγράμμιση αυτών των λιμένων με τους παγκόσμιους στόχους βιωσιμότητας.

Καθώς η παγκόσμια κοινότητα αντιμετωπίζει πιεστικές προκλήσεις, από την κλιματική αλλαγή και την οικολογική διατήρηση έως την ανάγκη για οικονομική ανάπτυξη χωρίς αποκλεισμούς, τα μικρομεσαία λιμάνια αντιμετωπίζουν την επιτακτική ανάγκη να συμβιβάσουν αυτές τις απαιτήσεις με τα συγκεκριμένα λειτουργικά τους πλαίσια. Η παρούσα διατριβή υπογραμμίζει ότι τα λιμάνια αυτά είναι η πηγή ζωής πολλών παράκτιων κοινοτήτων και αποτελούν αναπόσπαστο κομμάτι τόσο της περιφερειακής όσο και της εθνικής οικονομίας. Η αειφόρος ανάπτυξή τους, επομένως, έχει εκτεταμένες επιπτώσεις στην ευρύτερη οικονομική, κοινωνική και περιβαλλοντική ευημερία.

Μέσω της σύνθεσης διαφορετικών ερευνητικών μεθοδολογιών και της παρουσίασης πραγματικών περιπτώσιολογικών μελετών, αυτή η έρευνα όχι μόνο συμβάλλει στη συζήτηση για τη βιωσιμότητα των μικρών και μεσαίων λιμένων, αλλά προσφέρει επίσης πρακτική καθοδήγηση για τις λιμενικές αρχές, τους υπεύθυνους χάραξης πολιτικής και τους ενδιαφερόμενους του κλάδου. Υπογραμμίζει ότι τα μικρότερα λιμάνια, με τα μοναδικά χαρακτηριστικά τους, μπορούν να οδηγήσουν στον βιώσιμο σχεδιασμό, δείχνοντας ότι οι τοπικές δράσεις μπορούν να έχουν βαθύ αντίκτυπο στην παγκόσμια ατζέντα βιωσιμότητας.

Συμπερασματικά, η παρούσα διδακτορική διατριβή χρησιμεύει ως θεμελιώδης πηγή για όλους όσους ενδιαφέρονται για τον αειφόρο σχεδιασμό λιμανιών μικρού και μεσαίου μεγέθους. Όχι μόνο υπογραμμίζει τη σημασία αυτών των λιμένων στο παγκόσμιο εμπορικό δίκτυο, αλλά παρέχει επίσης εργαλεία για τη βιώσιμη ανάπτυξή τους, τονίζοντας τον ρόλο τους ως βασικοί μοχλοί περιφερειακής οικονομικής ανάπτυξης και περιβαλλοντικής διαχείρισης. Επιπλέον, καθώς ο θαλάσσιος κόσμος οδεύει προς ένα πιο βιώσιμο μέλλον, αυτή η έρευνα προσφέρει μια πυξίδα για να καθοδηγήσει τα μικρά και μεσαία λιμάνια στο ταξίδι τους προς την ανθεκτικότητα, την περιβαλλοντική ευθύνη και την οικονομική ευημερία.



## **Abstract**

As the global trade landscape evolves, ports of all sizes face increasingly complex challenges in pursuing sustainable development. Small and medium-sized ports (SMSPs), although often overshadowed by their larger counterparts in international trade and logistics discourse, hold a significant role in global supply chains and regional development. This doctoral Thesis presents a meticulous exploration of small and medium port sustainable planning, addressing the compelling need to understand, enhance, and advocate for the sustainability and resilience of these ports within the global maritime context.

The primary objectives of this research are the following:

1. Providing a guide for effective and efficient planning for the sustainability of SMSPs ports,
2. Use of the applied methodologies as decision-making tools aimed at optimizing sustainability,
3. Ranking of priorities for port sustainability improvement through stakeholders' perspectives,
4. Examining the degree of responsiveness /acceptance of stakeholders/citizens to the proposed sustainable development measures,
5. Identifying the main indicators covering the vital critical aspects of port sustainability objectives,
6. Evaluating and comparing sustainable indicators of different ports based on the application of best sustainable practices and
7. Identify and categorize threats prevalent among IoT devices in ports

Employing a multi-methodological approach that encompasses qualitative and quantitative analyses, case studies, cross-port comparisons, and active engagement with port stakeholders, this Thesis provides a holistic understanding of the multifaceted dimensions that shape sustainable planning within SMSPs. The research findings inform a comprehensive framework for sustainable planning, emphasizing the integration of economic, environmental, and social considerations and facilitating the alignment of these ports with global sustainability objectives.

As the global community confronts pressing challenges, from climate change and ecological preservation to the need for inclusive economic growth, SMSPs must reconcile these demands with their specific operational contexts. This Thesis emphasizes that these ports are the lifeblood of many coastal communities and are integral to regional and national economies. Their sustainable development, therefore, holds far-reaching implications for broader economic, social, and environmental well-being.

By synthesizing diverse research methodologies and presenting real-world case studies, this research not only contributes to the discourse on small and medium port sustainability but also offers practical guidance for port authorities, policymakers, and industry stakeholders. Their unique characteristics highlight that smaller ports can lead the way in sustainable planning, showcasing that local actions can profoundly impact the global sustainability agenda.

In conclusion, this doctoral Thesis is a foundational resource for all interested in the sustainable planning of SMSPs. It underscores the significance of these ports in the global trade network and provides tools for sustainable development, emphasizing their role as key drivers of regional economic growth and environmental stewardship. Furthermore, as the maritime world navigates towards a more sustainable future, this research offers a compass to guide SMSPs on their journey towards resilience, environmental responsibility, and economic prosperity.

## **Publications**

The following articles have been published in peer-reviewed scientific journals in the context of this doctoral Thesis:

Publications in scientific journals directly related to the PhD Thesis

1. Argyriou, I.; Sifakis, N.; Tsoutsos, T. Ranking Measures to Improve the Sustainability of Mediterranean Ports Based on Multicriteria Decision Analysis: A Case Study of Souda Port, Chania, Crete. *Environ Dev Sustain* 2022, 24, 6449–6466, <https://doi.org/10.1007/s10668-021-01711-7>
2. Argyriou, I.; Daras, T.; Tsoutsos, T. Challenging a Sustainable Port. A Case Study of Souda Port, Chania, Crete. *Case Stud Transp Policy* 2022, 10, 2125–2137, <https://doi.org/10.1016/j.cstp.2022.09.007>
3. Argyriou I, Tsoutsos T. Sustainable Solutions for Small/Medium Ports a Guide to Efficient and Effective Planning. *Journal of Marine Science and Engineering*. 2023; 11(9):1763. <https://doi.org/10.3390/jmse11091763>
4. Argyriou, I.; Nisiforou O.; Tsoutsos, T. Setting Sail for Growth: Assessing sustainable indicators in Small/Medium Ports (under review)
5. Argyriou I, Tsoutsos T., Assessing Critical Entities: Risk management for IoT devices in ports (under review)

## **Publications in international scientific conferences**

1. EinB2017 – “ENERGY in TRANSPORTATION 2017, ASHRAE Hellenic Chapter, October 21, 2017
2. 3rd International Conference “Ports, Maritime transport and insularity, Chamber of Commerce and Industry of Piraeus, 19-20 April 2018
3. EinB2019 – 8th International Conference “ENERGY in TRANSPORTATION 2019” Ashrae Hellenic Chapter, September 28, 2019
4. EU-Shipping-BCE 2022, Athens, 19-21 October 2022
5. Our Ocean Conference, Athens, 15-17 April 2024
6. 13th National Conference on Soft Forms of Energy, Athens 15-17 May 2024

# Table of contents

## Chapter 1-General information

1.	Introduction.....	23
1.1	General Concept.....	23
1.2	Aim.....	24
1.3	Research gaps.....	26
1.4	Research questions.....	27
1.5	Objectives.....	28
1.5.1	Providing a guide for effective and efficient planning.....	28
1.5.2	Examining the use of the applied methodologies as decision-making tools to optimize sustainability. ....	28
1.5.3	Ranking of priorities for port sustainability improvement through stakeholders' perspectives....	29
1.5.4	Examining the degree of responsiveness /acceptance of stakeholders/citizens to the proposed sustainable development measures.....	29
1.5.5	Identifying the main indicators covering the key critical aspects of port sustainability objectives.....	29
1.5.6	Evaluating and comparing different ports based on the application of best sustainable practices.....	30
1.5.7	Identify and categorize threats prevalent among IoT devices in ports.....	30
1.6	Originality.....	31
1.7	Contribution.....	33
1.8	Structure.....	35

## Chapter 2- Literature review

2.	Introduction.....	39
2.1	The concept of Sustainable Development .....	39
2.1.1	Environmental sustainability.....	39
2.1.2	Social sustainability.....	40
2.1.3	Economic sustainability.....	40
2.2	Historical background to the concept of sustainable development.....	41
2.3	Sustainable Development Goals (SDGs) for ports.....	43
2.4	Typologies of ports due to their size and operations.....	46
2.5	What problems do small/medium ports face for sustainability.....	48
2.5.1	Limited resources.....	48
2.5.2	Limited space.....	48
2.5.3	Limited access to technology and expertise.....	48
2.5.4	Lack of data.....	49

2.5.5	Inadequate infrastructure.....	49
2.5.6	Lack of awareness and education.....	50
2.6	Importance of ports.....	51
2.6.1	Importance of small/medium ports due to sustainable factors.....	51
2.6.2	Importance of ports due to their geographical position.....	53
2.6.2.1	Importance of EU ports .....	53
2.6.2.2	Importance of the Mediterranean ports.....	54
2.6.2.3	Importance of ports in Greece.....	55
2.7	Competent bodies/organizations in the context of sustainable development.....	56
2.8	Sustainable/green ports.....	58
2.9	Stakeholders in a port.....	58

## **Chapter 3-Sustainable Solutions for Small/Medium Ports: A Guide to Efficient and Effective Planning**

3.1	Introduction.....	61
3.2	Literature Review.....	64
3.2.1	Environmental Impact Assessment.....	65
3.2.2	Energy Efficiency.....	65
3.2.3	Stakeholder Engagement.....	66
3.2.4	Best or Most Suitable Practices.....	66
3.3	Methodology.....	68
3.4	Results.....	69
3.4.1	Phase 1: Assessment.....	72
3.4.1.1	Identify Environmental and Social Issues.....	72
3.4.1.2	Data Collection and Analysis.....	73
3.4.1.3	Evaluation of the Port's Infrastructure, Operations, and Environmental Impact.....	73
3.4.1.4	Risk Assessment.....	74
3.4.2	Phase 2: Stakeholder Engagement.....	74
3.4.2.1	Identify Stakeholders.....	74
3.4.2.2	Establish Communication Channels.....	75
3.4.2.3	Provide Information.....	75
3.4.2.4	Address Conflicts.....	75
3.4.2.5	Continual Engagement.....	75
3.4.3	Phase 3: Goal Setting.....	76
3.4.3.1	Assess the Current State.....	76
3.4.3.2	Identify Challenges and Opportunities.....	76
3.4.3.3	Involve Stakeholders.....	77
3.4.3.4	Establish Clear and Measurable Goals.....	77
3.4.3.5	Prioritize Goals.....	77

3.4.3.6	Communicate Objectives.....	77
3.4.3.7	Monitor and Evaluate Progress.....	78
3.4.4	Phase 4: Strategy Development.....	78
3.4.4.1	Examine Goals and Objectives.....	78
3.4.4.2	Conduct a Gap Analysis.....	79
3.4.4.3	Involve Stakeholders.....	79
3.4.4.4	Identify and Prioritize Strategies.....	79
3.4.4.5	Develop Implementation Plans.....	80
3.4.4.6	Communicate Strategies.....	80
3.4.4.7	Monitor and Evaluate Progress.....	80
3.4.5	Phase 5: Implementation.....	81
3.4.5.1	Allocate Resources.....	81
3.4.5.2	Establish a Project Team.....	81
3.4.5.3	Develop an Implementation Schedule.....	81
3.4.5.4	Communicate the Plan.....	82
3.5.5	Monitor Progress.....	82
3.5.6	Evaluate Outcome.....	82
3.6	Phase 6: Monitoring and Evaluation.....	82
3.6.1	Establish Monitoring and Evaluation Indicators.....	82
3.6.2	Develop a Monitoring and Evaluation Plan.....	83
3.6.3	Conduct Regular Monitoring.....	83
3.6.4	Evaluate Outcomes.....	83
3.6.5	Communicate Progress.....	84
3.6.6	Make Adjustments.....	84
3.7	Phase 7: Continuous Improvement.....	84
3.7.1	Lessons Learned.....	85
3.7.2	Identify New Challenges for the Next Plan.....	85
3.7.3	Update Port Planning Regularly.....	85
3.8	Conclusions.....	86

## Chapter 4- From the theoretical to the practical part of the PhD Thesis

4.1	Theoretical part.....	89
4.2	Practical part.....	89
4.3	The flow of PhD Thesis.....	90
4.4	Case studies.....	94
4.4.1	Crete.....	94

## **Chapter 5-Ranking measures to improve the sustainability of Mediterranean ports based on multicriteria decision analysis**

5.1	Introduction.....	99
5.2	Literature review.....	101
5.3	Methodology.....	104
5.3.1	Mathematical tools and models.....	104
5.3.2	Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE)	105
5.3.3	Profile of the respondents' panel.....	109
5.4	Results.....	112
5.4.1	Specific Criteria Weights.....	112
5.4.2	Implementation Timeframe of Actions /Cost.....	116
5.5	Conclusions.....	119

## **Chapter 6- Navigating the Port of Sustainability: Citizens' Perspectives and Challenges Explored**

6.1	Introduction.....	121
6.2	Literature review.....	124
6.2.1	Social sustainability.....	127
6.2.2	Environmental sustainability.....	127
6.2.3	Economic sustainability.....	127
6.3.	Proposed measures.....	128
6.4.	Description of sampling.....	130
6.5	Methodology (Mathematical tools and models) .....	131
6.5.1	Mathematical tools.....	131
6.5.2	Mathematical models.....	131
6.6	Results.....	134
6.6.1	Based on KPIs.....	134
6.6.2	Based on the Software Package for the Social Sciences (SPSS).....	137
6.6.3	Based on Factor Analysis.....	139
6.7	Conclusions.....	144

## **Chapter 7-Assessing Sustainable Indicators in Small/Medium Ports**

7.1	Introduction.....	147
7.2	Literature review.....	149
7.3	Sustainable indicators.....	150
7.3.1	Environmental sustainability/indicators.....	150
7.3.2	Economic sustainability/indicators.....	151
7.3.3	Social sustainability/indicators.....	151



7.4	Main indicators.....	152
7.4.1.	Green infrastructure.....	152
7.4.2.	Environmental Monitoring and Management.....	152
7.4.3	Management energy.....	152
7.4.4	Technology.....	153
7.4.5	Approaches for waste management and recycling.....	153
7.4.6	Training of employees in environmentally responsible practices.....	153
7.4.7	Security of employment and social protection.....	154
7.4.8	Competitiveness.....	154
7.5	Case studies/Identification of experts.....	157
7.6	Description of phases.....	158
7.7	Methodology.....	160
7.8	Results.....	162
7.8.1	Best worst method.....	162
7.8.2	Ports assessed using the VIKOR method.....	168
7.9	Conclusions.....	169

## **Chapter 8-Risk management for IoT devices in ports**

8.1	Introduction.....	171
8.2	Literature review.....	173
8.3	Methodology.....	180
8.3.1	Mathematical tool and model.....	180
8.3.2	Description of survey phases.....	183
8.4	Results.....	183
8.4.1	Results by factor.....	183
8.4.1.1	Terrorism.....	183
8.4.1.2	Pandemic.....	184
8.4.1.3	Huma effect.....	186
8.4.1.4	Cyber attacks.....	186
8.4.1.5	Maintenance.....	187
8.4.1.6	Natural disaster.....	188
8.4.2	Overall results.....	189
8.4.3	Discussion of the results.....	190
8.5	Conclusions.....	192

## **Chapter 9-Conclusions**

9.1	Discussion on the objectives of PhD Thesis.....	195
9.1.1	Providing a guide for effective and efficient planning.....	195
9.1.2	Examining the use of the applied methodologies as decision-making tools to optimize sustainability. ....	196
9.1.3	Ranking of priorities for port sustainability improvement through stakeholders' perspectives	197
9.1.4	Examining the degree of responsiveness /acceptance of stakeholders/citizens to the proposed sustainable development measures.....	198
9.1.5	Identifying the main indicators covering the vital critical aspects of port sustainability objectives.....	198

9.1.6	Evaluating and comparing different ports based on the application of best sustainable practices.....	199
9.1.7	Identify and categorize threats prevalent among IoT devices in ports.....	201
9.2	Future recommendations.....	201
9.3	Limitations of PhD Thesis.....	203

# Appendices

	<b>Appendix A</b>	
<b>Table A1</b>	Aggregate weights of main and sub-indicators for all experts (CHA-port).....	205
<b>Table A2</b>	Aggregate weights of main and sub-indicators for all experts (RET-port) .....	206
<b>Table A3</b>	Aggregate weights of main and sub-indicators for all experts (SIT-port) .....	207
	<b>Appendix B</b>	
<b>Table B1</b>	Terrorism.....	208
<b>Table B2</b>	Pandemic.....	208
<b>Table B3</b>	Human effect.....	209
<b>Table B4</b>	Cybersecurity.....	210
<b>Table B5</b>	Maintenance.....	210
<b>Table B6</b>	Natural disasters.....	211
<b>Bibliography</b> .....		212

# List of tables

<b>Table 2.1</b>	Port categories.....	46
<b>Table 3.1</b>	Targets for the proposed planning.....	69
<b>Table 5.1</b>	Profile of the respondents' panel.....	108
<b>Table 5.2</b>	Relative weights of participant w.r.t. participants groups.....	110
<b>Table 5.3</b>	Advantages and disadvantages of each measure.....	118
<b>Table 6.1</b>	Advantages and disadvantages of studying stakeholders'/citizens' views.....	122
<b>Table 6.2</b>	Measures to improve the social indicators.....	128
<b>Table 6.3</b>	Measures to improve the environmental indicators.....	129
<b>Table 6.4</b>	Measures to improve the economic indicators.....	130
<b>Table 6.5</b>	Profile of the sample.....	130
<b>Table 6.6</b>	KPI computation for the question $x_i$ w.r.t gender.....	132
<b>Table 6.7</b>	Gender and age distribution of the population of Greece.....	132
<b>Table 6.8</b>	KPIs related to gender and age.....	133
<b>Table 6.9</b>	Chi-square tests w.r.t. gender.....	137
<b>Table 6.10</b>	Chi-square tests w.r.t. age.....	138
<b>Table 6.11</b>	Chi-square tests and KPIs w.r.t. level of education.....	139
<b>Table 6.12</b>	Factor analysis indexes per part.....	140
<b>Table 6.13</b>	Interpretation of factors.....	142
<b>Table 6.14</b>	Factors and loading.....	143
<b>Table 7.1</b>	Main and sub-indicators to evaluate the ports' sustainable performance.....	155
<b>Table 7.2</b>	Scale for comparison matrix according to the VIKOR methodology.....	159
<b>Table 7.3</b>	Total number of experts who selected specific criteria as best and worst, respectively	162
<b>Table 7.4</b>	Aggregate weights of main and sub-criteria for all experts (HRA-port).....	164
<b>Table 7.5</b>	Results for each port and each criterion, considering all expert responses.....	165
<b>Table 7.6</b>	S, R, and Q values.....	168
<b>Table 8.1</b>	List of the potential IoT hazards.....	180
<b>Table 8.2</b>	Risk Assessment Matrix.....	182
<b>Table 8.3</b>	Risk Matrix based on results.....	190
<b>Table 8.4</b>	Assessment of scenarios.....	190

# List of Figures

<b>Figure 1.1</b>	Gap analysis.....	27
<b>Figure 2.1</b>	Sustainable development Goals.....	44
<b>Figure 2.2</b>	Categorization of ports.....	47
<b>Figure 2.3</b>	The gross weight of seaborne freight handled in all ports, EU, 2007-2022 (million tonnes) .....	53
<b>Figure 2.4</b>	Gross weight seaborne handled in all ports, 2022 (tonnes per capita).....	54
<b>Figure 2.5</b>	Main stakeholders of ports.....	59
<b>Figure 3.1</b>	Areas of comparison between the traditional and proposed planning.....	70
<b>Figure 3.2</b>	Phases and steps of the proposed methodology.....	72
<b>Figure 4.1</b>	Steps of PhD Thesis.....	93
<b>Figure 5.1</b>	Stages of the proposed methodology.....	108
<b>Figure 5.2</b>	Top 10 environmental priorities of European port for the year 2023.....	114
<b>Figure 5.3</b>	Maximum and minimum scores for each sector.....	114
<b>Figure 5.4</b>	Promethee II phi values.....	115
<b>Figure 5.5</b>	Implementation/Time frame of actions/costs.....	117
<b>Figure 6.1</b>	Financial contributors to the creation of a sustainable port.....	135
<b>Figure 6.2</b>	Social assessment KPIs.....	136
<b>Figure 6.3</b>	Economic assessment KPIs.....	136
<b>Figure 6.4a</b>	Environmental quality indexes.....	136
<b>Figure 6.4b</b>	Environmental problems.....	136
<b>Figure 6.4c</b>	RES endorsement.....	136
<b>Figure 6.5</b>	KPI values per sustainability pillar/part.....	136
<b>Figure 7.1</b>	Statistical data.....	158
<b>Figure 7.2</b>	Stages of the recommended method.....	159
<b>Figure 7.3</b>	Priorities for main indicators for each port.....	166
<b>Figure 7.4</b>	Priorities for sub-indicators for each port.....	166
<b>Figure 8.1</b>	Flowchart-Steps of the proposed methodology.....	180

### Abbreviations

American Association of Port Authorities	AAPA	Keiser Meyer Olkin	KMO
Bachelor degree	BA	Key Performance Indicators	KPIs
Competitiveness	CMS	Management of energy	ME
Critical entities	CEs	Master's degree	MSc
Doctor of Philosophy degree	PhD	Monitoring and evaluation	M&E
Environmental management systems	EMS	Multi-Criteria Decision Analysis	MCDA
Environmental Monitoring and Management	EMM	Operational risk management	ORM
Environmental Ship Index	ESI	Port Environmental Review System	PERS
European Green Deal	EGD	Port of Heraklion	HER
European Maritime Safety Agency	EMSA	Port of Rethymnon	RET
European Resources Planning	ERP	Port of Sitia	SIT
European Sea Ports Organization	ESPO	Port of Souda, Chania	CHA
European Sustainable Shipping Forum	ESSF	Preference Ranking Organization Method for	
European Union	EU	Enrichment of Evaluations	PROMETHEE
Fuel cell electric vehicles	FCEVs	Renewable energy sources	RES
Global Reporting Initiative	GRI	Security of Employment and Social Protection	SE&SP
Greenhouse gas	GHG	Small/medium-sized ports	SMSPs
Green Infrastructure	GI	Software Package for the Social Sciences	SPSS
High School		Sustainable Development Goals	SDGs
		Technology	TE
International Maritime Organization	IMO	Training of employees in environmentally	
Internet of Things	IoT	responsible practices	EET
		United Nations Environmental Program	UNEP
Junior High School	JHS	Vlsekriterijumska Optimizacija I Kompromisno	
		Resenje	VIKOR

# **Chapter 1- Introduction**

## **1. Introduction**

### **1.1 General Concept**

In an interconnected world, seaports have long played a pivotal role in facilitating trade, supporting economic growth, and enabling the exchange of goods and ideas (Lane and Pretes, 2020). As global trade expands, ports of all sizes face immense challenges in their quest for sustainable development (González-Laxe et al., 2023). The need to balance economic growth with environmental conservation, social well-being, and operational efficiency is more pressing than ever. In this complex context, the focus of this doctoral Thesis emerges.

Small and medium-sized ports represent a significant but often understudied component of the maritime landscape (Mio et al., 2020). While the world's major ports garner considerable attention in international trade and logistics discussions, smaller ports are equally vital and face distinct challenges and opportunities. Their unique characteristics, including limited resources, community interfaces, and diverse operational roles, necessitate a specialized approach to sustainable planning.

This Thesis embarks on a comprehensive examination of small and medium port sustainable planning, aiming to fill critical gaps in the existing literature and provide a foundational tool for policymakers, industry stakeholders, and researchers alike. Through a multidisciplinary approach, we delve into the intricacies of port operations, management, and development, framed within the broader context of sustainability. By doing so, we seek to address the questions surrounding these ports' sustainability, resilience, and contributions to regional and global economies.

The objectives of this study are manifold: to review state of the art in small and medium port sustainability planning; to identify the specific challenges and opportunities faced by these ports in a rapidly evolving global landscape; to extract best practices, innovative strategies, and successful case studies that promote sustainability in small and medium port settings; and to construct a comprehensive framework for sustainable planning tailored to the unique requirements of smaller ports.

To accomplish these goals, this research adopts a multi-methodological approach that includes qualitative and quantitative analyses, case studies, comparative assessments, and active engagement with port stakeholders. Drawing upon these methodologies, this Thesis aspires to offer an integrated understanding of the complex dynamics that shape sustainable planning in small and medium-sized ports.

Therefore, this study embarks on a journey of exploration, investigation, and transformation, hoping its findings will contribute to a broader conversation about sustainable planning for ports of all sizes. By placing small and medium-sized ports at the center of the sustainability discourse, this research endeavors to chart a course for these ports to become resilient, environmentally responsible, and economically viable players in the maritime world. The following chapters delve into the multifaceted world of sustainable planning for small and medium ports, aspiring to guide these ports toward a sustainable, prosperous, and environmentally responsible future.

## **1.2 Aim**

SMSPs play a crucial role in the global economy by facilitating the movement of goods and people, yet they often confront unique sustainability issues. This Thesis on small and medium port sustainability planning aims to address the pressing challenges these vital maritime hubs face in a rapidly changing global landscape. This research seeks to identify, understand, and propose solutions to these challenges to enhance these ports' resilience and environmental responsibility.

One key aim of this research is to assess the environmental impact of SMSPs. Ports are known sources of pollution and ecological disruption, but the magnitude of these effects in smaller ports needs to be well-documented. By quantifying these impacts, the research aims to develop strategies for mitigating environmental harm and promoting sustainable practices tailored to smaller port facilities' specific needs and limitations.

Another important aim of this research is to examine the economic sustainability of SMSPs. These ports often face financial constraints and intense competition. Investigating how these ports can maintain profitability while adhering to sustainability principles is a critical aspect of the research. Identifying strategies that work for smaller ports can help them thrive in a global economy that increasingly values sustainable practices.

One additional aim of the research is to foster innovation and technology adoption within these ports. Innovation can be a driving force in reducing environmental impact, increasing efficiency, and enhancing the overall sustainability of small and medium-sized ports. This research seeks to identify and evaluate emerging technologies, digitalization, and best practices that can be integrated into port operations. Doing so aims to pave the way for more environmentally friendly and efficient port management.



Furthermore, the research aims to empower the social dimension of sustainability in small and medium ports. It will examine the impact of these ports on local communities and the well-being of the people living in and around them. The aim is to find strategies that promote social responsibility with community engagement, ensuring the success of implementing a sustainable port development plan.

Moreover, this Thesis aims to comprehensively evaluate and analyze the sustainable indicators employed at ports. It seeks to investigate, assess, and compare the diverse range of sustainability measures and metrics implemented within port operations, aiming to discern their efficacy, applicability, and impact on environmental, social, and economic dimensions. Through a multifaceted examination, this study aims to provide insights into best practices, challenges, and opportunities for enhancing sustainability within port environments, contributing to advancing sustainable practices in the global maritime industry.

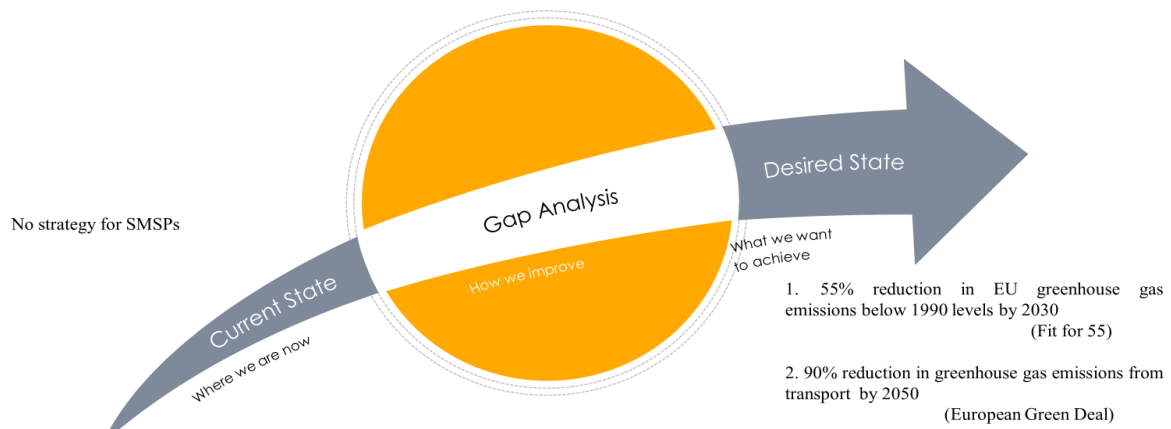
Additionally, this study aims to comprehensively assess the vulnerabilities, threats, and potential risks associated with integrating IoT devices in port environments, considering factors such as cybersecurity, data privacy, operational disruptions, and natural disasters. By identifying and evaluating these risks, the Thesis aims to develop proactive and adaptive risk management frameworks that mitigate vulnerabilities and bolster the resilience of IoT systems in ports.

In summary, this multi-faceted Thesis on small and medium port sustainability planning encompasses environmental, economic, governance, technological, and social dimensions. By investigating and addressing these aspects, the research seeks to provide a comprehensive understanding of these ports' challenges and opportunities. The ultimate aim is to develop a framework for sustainable port planning that supports small and medium ports' long-term viability and positive contributions to local, national, and global economies while minimizing their negative environmental and social impacts.

### 1.3 Research gaps

Small/medium port sustainability is a multifaceted domain that addresses many environmental, social, economic, and operational challenges. As the global community increasingly acknowledges the importance of sustainable port operations, the need to understand these multivarious dimensions better becomes evident. Within the expansive research landscape on small/medium port sustainability, gaps, and uncharted territories serve as intriguing opportunities for researchers. This Thesis aims to illuminate the unexplored spaces on small/medium port sustainability, identifying critical gaps in knowledge, methodologies, and practical approaches that demand scholarly attention. Recognizing the complexities and intricacies inherent in the field of study, it is vital to begin by highlighting the research gaps and uncharted territories that need further exploration and that our research will seek to cover.

- a. Firstly, while larger ports benefit from established sustainability frameworks and guidelines, smaller ports remain an area that needs to be adequately explored.
- b. Secondly, while several studies focus on individual initiative solutions to solve sustainability problems, the literature must reference the sustainability-oriented integrated planning approach in small/medium ports.
- c. While the environmental dimensions have received significant attention, there is a research gap concerning sustainability initiatives' economic and social viability; more research is needed on the economic and social aspects of sustainability planning in small and medium-sized ports.
- d. Another critical research gap involves the development of innovative performance metrics and indicators specifically designed for small and medium-sized ports. Existing sustainability assessment tools are often geared towards larger ports and must capture the unique impacts and challenges their smaller counterparts face.
- e. An additional conspicuous research gap pertains to the limited attention given to port sustainability from the perspective of the citizens who reside near these vital maritime hubs rather than stakeholders.
- f. Despite the growing reliance on IoT devices to enhance operations and security in ports, there remains a significant research gap in understanding the full spectrum of potential threat vectors specific to these interconnected systems in the maritime environment.



**Figure 1.1. Gap analysis**

Figure 1.1 depicts the main gap of the PhD Thesis, which focuses on the lack of an existing strategy for sustainability for SMSPs.

By revealing these gaps, this study aims to provide a comprehensive roadmap for future research endeavors, enabling a more holistic and sustainable evolution of our ports in an ever-changing world.

#### **1.4 Research questions**

The identification of the objectives and research gaps of the present research dissertation is linked to its main research questions, which are formulated as follows:

1. How can small and medium-sized ports develop comprehensive and adaptive sustainability plans that address environmental, economic, and social dimensions while considering their unique resource constraints and operational scales? (see Chapter 3, par.1, page 63)
2. What benefits can small/medium ports derive from sustainable planning? (see Chapter 3, par.1, page 63)
3. What is the degree of acceptance of stakeholders in the application of new technologies (smart networks, cold ironing) that are conducive to green development? (see Chapter 5, par.1, page 100)
4. What is the degree of response/acceptance to the proposed measures for sustainable development of ports by the citizens (see Chapter 6 par.1 pag.124)
5. What core sustainability indicators benchmark port performance regarding environmental, social, and economic sustainability, and how do these indicators vary across different regions and port sizes? (see Chapter 6 par.1 pag.148)

6. What are the primary security threats and vulnerabilities associated with IoT devices deployed in port environments, and what strategies can be implemented to ensure resilience and continuity of port operations in the face of these vulnerabilities? (see Chapter 8, par.1, page 173)

## **1.5 Objectives of the survey**

The objectives of this Thesis on port sustainability planning encompass a range of goals aimed at understanding, improving, and promoting sustainability within the maritime industry. These objectives include:

### **1.5.1 Providing a guide for effective and efficient planning (see Chapter 3)**

Developing a guide tailored specifically for effective and efficient planning for small and medium-sized ports is crucial, as these ports have unique challenges and opportunities distinct from their larger counterparts. Such a guide should optimize resource allocation, enhance stakeholders' participation, and improve the environmental sector. It should also emphasize sustainability measures appropriate to the scale of operations and address these ports' vital role in local economies and communities. By offering targeted guidance for small and medium ports, the proposed planning enables stakeholders to navigate the complexities of planning, facilitating their growth, job creation, and sustainability efforts while ensuring they remain resilient and competitive in the maritime landscape.

### **1.5.2 Examining the use of the applied methodologies as decision-making tools aimed at optimizing sustainability (see Chapter 5)**

Examining applied methodologies as decision-making tools to optimize port sustainability reveals a multifaceted approach to addressing modern maritime hubs' complex challenges. As crucial nodes in global trade networks, ports play a pivotal role in the movement of goods and are simultaneously exposed to environmental, economic, and social pressures. One critical methodology that has gained prominence is the application of multicriteria practices. Examining applied methodologies, such as multicriteria analysis, as decision-making tools to optimize port sustainability provides valuable insights into the complex interplay of factors involved in port management. Multicriteria analysis is a versatile approach that enables decision-makers to assess various factors simultaneously, accounting for economic, environmental, and social dimensions.

One of the notable advantages of multicriteria analysis in the context of port sustainability is its ability to engage stakeholders effectively.

### **1.5.3 Ranking of priorities for port sustainability improvement through stakeholders' perspectives (see Chapter 5)**

Ranking priorities for port sustainability improvement through stakeholders' perspectives is critical in fostering inclusive and effective decision-making processes. Engaging stakeholders from diverse backgrounds, including port authorities, residents, shipping companies, environmental groups, and government agencies, is essential in identifying and addressing the most pressing sustainability challenges. By involving these key players, it becomes possible to create a comprehensive list of priorities reflecting port operations' multifaceted nature and their influence on various aspects of society.

### **1.5.4 Examining the degree of responsiveness /acceptance of stakeholders/citizens to the proposed sustainable development measures (see Chapter 6)**

Examining the degree of responsiveness and acceptance of stakeholders/citizens to the proposed sustainable development measures is vital to ensuring the successful implementation of sustainability initiatives. Their willingness to support and actively engage with proposed measures can significantly impact sustainability projects' effectiveness and long-term success. Evaluating their responses provides valuable insights into aligning proposed initiatives with stakeholders' values, expectations, and concerns. Addressing concerns and adapting proposed measures based on stakeholders'/citizens' feedback is essential to foster greater buy-in and collaboration.

### **1.5.5 Identifying the main indicators covering the vital critical aspects of port sustainability objectives (see Chapter 7)**

Identifying the main indicators that cover the key critical aspects of port sustainability objectives is essential in ensuring that a port operates in a manner that aligns with its environmental, social, and economic responsibilities. Sustainability in port operations encompasses many factors, including environmental impact, social well-being, and economic performance. These indicators are valuable tools for quantifying and monitoring progress in each dimension. By identifying and tracking these main indicators, port authorities can evaluate their performance in each of these

critical aspects and take informed steps toward achieving sustainability objectives while balancing the interests of all stakeholders.

#### **1.5.6 Evaluating and comparing different ports based on the application of best sustainable practices (see Chapter 7)**

Evaluating and comparing different ports based on their application of best sustainable practices is a multifaceted endeavor that promotes healthy competition and provides valuable insights for continuous improvement. Sustainable practices in the maritime industry are essential for mitigating environmental impact, enhancing community well-being, and ensuring economic resilience.

#### **1.5.7 Identifying and categorizing threats prevalent among IoT devices in ports (see Chapter 8)**

The objectives aimed at identifying and categorizing threats prevalent among IoT devices in ports are centered around a systematic and thorough analysis of the diverse range of potential risks within this domain. The primary objective involves conducting an extensive review of existing literature, case studies, and empirical data to compile a comprehensive inventory of threats confronting IoT devices in port environments. This process will entail recording various types of threats, including but not limited to cybersecurity vulnerabilities, physical breaches, data manipulation, network intrusions, and vulnerabilities arising from inter-device communication protocols. Ultimately, the objectives aim to establish a robust foundation for formulating tailored risk management strategies to mitigate and address the identified threats effectively.

In conclusion, the ultimate goal of the dissertation is to equip small/medium port authorities and stakeholders with a set of practical tools and guidelines that facilitate the improvement of sustainability, leading to more environmentally responsible, socially engaged, and economically viable small ports.

## 1.6 Originality

In the age of global interconnectedness and heightened environmental awareness, the pursuit of originality in research is urgent, particularly within port sustainability. The small/medium ports, which are pivotal hubs for trade and pleasure, have become the epicenters of a critical and burgeoning challenge: balancing economic growth with environmental preservation. With mounting concerns over climate change, resource depletion, and the ecological impact of maritime activities, the quest for innovative solutions within the realm of port sustainability becomes a scholarly endeavor and a global imperative. This research paper embarks on a procedure to uncover fresh perspectives, innovative technologies, and sustainable strategies, contributing to the ongoing attempt surrounding port sustainability and offering scientific tools for a more harmonious future between trade and ecological well-being. More specifically, the originality of the research is based on the following issues:

- a. Firstly, the originality of this research lies in its holistic perspective, considering not only environmental sustainability but also social and economic dimensions. While environmental aspects often take the forefront in sustainability discussions, this research recognizes that true sustainability encompasses a broader spectrum of factors. By examining the social and economic impacts of sustainability planning in small and medium-sized ports, including labor practices, community engagement, and economic inclusivity, this research provides a well-rounded perspective that can guide small/medium ports toward comprehensive and original sustainability solutions that benefit not only their ecological footprint but also the well-being of their communities and stakeholders.
- b. Secondly, the originality of this research for port sustainability planning for small/medium ports is further underscored by its emphasis on innovative partnerships. Often, SMSPs need more resources to address sustainability challenges fully on their own. This research explores novel approaches to fostering collaboration among stakeholders, including public and private entities and local communities. More specifically, this research offers the potential for collective action and shared responsibility in achieving sustainability goals. This approach recognizes that the success of sustainability planning for these ports depends on individual efforts and building networks of support and cooperation.
- c. Expanding on the originality of this research, it's important to note that it strongly emphasizes stakeholder inclusivity and community-centered approaches. Many sustainability

planning efforts in small and medium-sized ports have traditionally been top-down, where the government or port authority sets the strategic intent and prepares the plan, with limited input from the local communities and stakeholders that these ports often directly impact. This research seeks to propose methods for actively involving community members, local businesses, and environmental organizations in the decision-making processes related to port sustainability. By placing a greater focus on community engagement, this research aims to build a sense of shared responsibility for sustainability initiatives, fostering a more democratic and inclusive approach to port planning that has the potential to yield innovative solutions based on the wisdom and perspectives of those directly affected.

d. Research on small/medium port sustainable planning is still in its early stages, and there are many opportunities for original contributions to the field. One area where research is needed is the development of novel tools and methods for assessing the sustainability of small ports. While there is a growing interest in sustainability assessment frameworks and performance metrics for ports, much of this work has focused on large ports and has yet to fully address the unique challenges and opportunities facing small and medium-sized ports. Research in this area will help develop more tailored and effective sustainability assessment tools and metrics designed explicitly for small port contexts.



## 1.7 Contribution

The contribution of research on port sustainability planning for small and medium-sized ports is substantial and encompasses several critical aspects.

1. First and foremost, this research elevates the significance of sustainability planning in smaller ports. Often overshadowed by larger counterparts, small and medium-sized ports play a pivotal role in regional and global trade. Research in this domain emphasizes that sustainability planning is not exclusive to significant hubs but should be ingrained in the ethos of all ports, regardless of their scale. This shift in perspective fosters a more comprehensive and inclusive approach to sustainability within the maritime sector.

2. Secondly, research in this field directly contributes to environmental conservation and resilience. Many small and medium-sized ports are situated in ecologically sensitive areas, making their sustainable operation crucial for safeguarding ecosystems. Research endeavors focus on developing strategies to minimize environmental impact, reduce emissions, protect marine habitats, and adapt to climate change. The findings offer actionable insights for mitigating the maritime industry's ecological footprint, aligning with global sustainability objectives.

Thirdly, this research offers economic benefits by enhancing smaller ports' competitiveness and financial sustainability.

3. These ports can achieve cost savings and attract environmentally conscious investors by optimizing resource usage, reducing energy consumption, and implementing eco-friendly technologies. This, in turn, contributes to the economic development of the regions they serve, creating jobs and fostering economic growth.

4. Moreover, research on port sustainability planning emphasizes the social responsibility aspect of port operations. Ports play a significant role in local communities, making their social impact a critical consideration. This research delves into strategies for engaging with local citizens and stakeholders, ensuring their voices are heard and that sustainability plans address their concerns. By promoting inclusive practices and improving the quality of life for surrounding communities, ports can become more socially responsible entities.

5. This research is a valuable resource for the broader maritime industry. Small and medium-sized ports are interconnected nodes in the global supply chain. Insights and best practices developed through this research can be shared and adapted by ports worldwide. This fosters a

collaborative culture of sustainability across the industry, with ports learning from each other's experiences and collectively advancing the cause of sustainability in maritime operations.

6. Lastly, research on port sustainability planning encourages a holistic approach to sustainability. It underscores that sustainability is not a one-dimensional concept but involves a delicate balance between environmental, economic, and social considerations. This research advocates for a comprehensive understanding of sustainability by addressing all these dimensions. It emphasizes the importance of tailoring sustainability plans to local contexts and constraints, ensuring they are both effective and feasible.

In conclusion, research on port sustainability planning for small and medium-sized ports has far-reaching implications. It promotes a more inclusive, environmentally conscious, economically viable, and socially responsible maritime industry. Through investigation and dissemination of best practices, this research drives progress toward a future where sustainability is not merely a goal but an integral part of port operations, benefiting local communities, the global environment, and the industry.

## 1.8 Structure

Chapter 1, "Introduction", outlines the research gaps in port planning, shedding light on small and medium ports' challenges, complexities, and unique characteristics. It articulates the study's research objectives, methodology, and scope, providing a roadmap for the subsequent chapters. The introduction aims to captivate the reader's interest, establish the relevance of the research, and lay the groundwork for the in-depth exploration of issues pertinent to small and medium port planning throughout the Thesis.

Chapter 2, "The Literature Review," forms a critical foundation by synthesizing existing knowledge, theories, and research findings related to the subject. It encompasses an extensive examination of scholarly articles, books, reports, and other relevant sources to comprehensively understand the complexities of port planning within the context of smaller-scale maritime infrastructure. This section delves into various aspects, including but not limited to port governance structures, environmental sustainability, operational efficiency, economic impacts, technological advancements, and the socio-economic dynamics influencing these ports.

Chapter 3 describes a comprehensive guide to efficient and effective sustainable port planning focused on enhancing ports' social, economic, and environmental aspects. This guide encapsulates a systematic framework delineating the key steps for fostering sustainability in port planning and operations. It encompasses a multifaceted approach that integrates ecological, social, and economic dimensions, emphasizing strategies for reducing environmental impact, optimizing resource utilization, and fostering community engagement. By providing a structured roadmap and actionable recommendations, this guide seeks to empower port authorities, policymakers, and stakeholders with the tools necessary to navigate the complexities of sustainable port planning, driving towards a more resilient, environmentally responsible, and economically viable port industry.

Chapter 4 describes the transition from the theoretical part to the practical and analyzes the areas covered by the case studies. Including case studies is pivotal to illustrating theoretical concepts and validating empirical findings. These case studies involved an in-depth analysis of specific small or medium-sized ports from various geographical locations, examining their unique characteristics, challenges, strategies, and successes in port planning and management. Through detailed exploration and comparison, these case studies offered valuable insights into the real-world complexities faced by smaller ports, including issues related to infrastructure development,

technological integration, environmental sustainability, stakeholder engagement, and economic impacts. By presenting diverse case studies, the Thesis aims to provide a nuanced understanding of the multifaceted nature of small and medium port operations, offering practical implications and recommendations for enhancing their efficiency, resilience, and competitiveness within the global maritime landscape.

Chapter 5, focused on ranking measures to enhance sustainability for small and medium ports, forms a critical framework to assess, evaluate, and prioritize strategies conducive to sustainable development within these port entities. This section comprehensively analyzes diverse sustainability measures encompassing environmental, social, and economic dimensions, such as carbon footprint reduction, waste management, community engagement, energy efficiency, and resilience to climate change. This part of the Thesis establishes a systematic ranking system through quantitative and qualitative methodologies, employing criteria and indicators tailored to the specific context of small and medium ports. It aims to identify and prioritize the most impactful and feasible sustainability measures, offering a structured approach to support port authorities and stakeholders in decision-making processes to enhance sustainability practices. By providing a ranked framework, this survey contributes to the strategic planning and implementation of measures that can effectively promote sustainability, resilience, and competitiveness for small and medium ports in the maritime industry.

Chapter 6 explores citizens' perspectives on port sustainable planning and is a crucial exploration into the sociocultural dimensions shaping the relationship between ports and their surrounding communities. This segment employs qualitative research methods such as surveys, interviews, and participatory approaches to capture and analyze residents' viewpoints, concerns, and aspirations directly impacted by port activities. By delving into these perspectives, the Thesis aims to uncover community needs, preferences, and perceptions regarding environmental impacts, quality of life, employment opportunities, and overall social well-being influenced by port operations. Understanding citizen perspectives enables the formulation of inclusive and community-oriented sustainable port planning strategies that address environmental concerns and align with the local population's socio-economic aspirations.

Chapter 7 thoroughly analyzes diverse indicators spanning environmental, social, and economic dimensions tailored to smaller ports' unique characteristics and challenges. Through quantitative analysis, qualitative assessments, and benchmarking, this Thesis section identifies and evaluates

key performance indicators encapsulating the port's sustainability efforts. These indicators included measures related to carbon emissions, energy efficiency, waste management, and climate change. By systematically assessing sustainable indicators, this Thesis enhances sustainability initiatives' accountability, transparency, and effectiveness in small and medium ports, providing valuable insights to stakeholders and decision-makers to drive continual improvement and foster a more sustainable maritime industry.

Chapter 8, focused on risk management for Internet of Things (IoT) devices in ports, is a critical exploration into mitigating vulnerabilities and enhancing security within the increasingly interconnected and digitized port infrastructure. This segment comprehensively analyzes potential threats, vulnerabilities, and risks associated with deploying and integrating IoT devices in port operations. It examines various aspects, including cybersecurity threats, system reliability, natural disasters, and the potential impact of disruptions on port functionalities. By employing risk assessment frameworks, this chapter delves into strategies to mitigate risks and fortify the resilience of IoT devices used in ports.

Chapter 9, “General Conclusion,” consolidates the findings, insights, and contributions garnered throughout the research journey. It highlights the significance of sustainable practices, effective planning methodologies, and the integration of technological advancements in fostering resilient and competitive small and medium ports. Moreover, it underlines the importance of community engagement and stakeholder collaboration in achieving sustainable and inclusive port development. The future perspectives section extrapolates potential avenues for further research, emphasizing emerging trends, evolving technologies, and regulatory frameworks that may shape the landscape of small and medium port planning. However, this Thesis also acknowledges its limitations, such as constraints in data availability, scope constraints in the analysis, and potential biases in methodologies employed, thus encouraging future researchers to address these gaps for a more comprehensive understanding of sustainable small and medium port planning.

## **Chapter 2-Literature review**

## **2. Literature review**

### **2.1 The Concept of Sustainable Development**

The concept of sustainability has become an integral part of development planning since the late 1980s and has evolved in recent years. Defining sustainability is a complex task, as it is a broad and profound concept that depends on many factors. The definition of sustainable development, according to the literature, has made the academic field quite difficult over the years as there are many opinions and concepts (Mio et al., 2020). According to many researchers, sustainable development is linked to many factors, such as the environment, economy, and society.

To create a basis, it is essential to understand the most accepted definition of Sustainable Development. The purpose of sustainable development, in the meaning attributed to it today, only formed in the last decades of the 20th century. It emerged from a shift in perception, initially expressed as a concern about environmental problems, the impact of environmental degradation on people's health and quality of life, economic growth, and the realization that natural resources needed to be preserved for future generations. The most widely accepted concept of sustainable development emerged from the work of the United Nations General Assembly in 1987, which published a report entitled "Our Common Future," also known as the "Brundtland report," in which sustainable development was defined as: "Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Shi et al., 2019) The United Nations, the Organisation for Economic Co-operation and Development, and the World Bank, have widely adopted this definition. To understand sustainability in depth, one must consider the three main zones of influence separately, the so-called "Three Pillars of Sustainability," with their respective social, economic, and environmental aspects.

#### **2.1.1 Environmental sustainability**

Environmental sustainability in small/medium ports is an increasingly crucial focus within the maritime industry, aiming to mitigate the ecological impact of port operations while fostering long-term environmental stewardship (Acciaro et al., 2014). As vital nodes in global trade networks, Ports have recognized the imperative to reduce their ecological footprint by implementing sustainable practices (Brunila et al., 2023). Efforts toward environmental sustainability encompass a spectrum of initiatives, including adopting cleaner fuels to minimize air pollutants emitted by

vessels and port machinery, implementing energy-efficient technologies to reduce power consumption, and utilizing renewable energy sources (RES) like solar or wind power (Lalla-Ruiz et al., 2018). Additionally, SMSPs are increasingly investing in innovative waste management systems to minimize marine litter and pollutants and initiatives to protect and restore local ecosystems affected by port activities (Osmundsen, 2023). These sustainability endeavors align with global environmental commitments and uphold the reputation of ports as responsible corporate citizens contributing to the preservation of the surrounding environment and ecosystems. However, achieving environmental sustainability at ports presents multifaceted challenges. Balancing the demands of economic growth and trade facilitation with environmental preservation requires careful navigation and strategic planning. Ports often need more space for green infrastructure (GI) development, financial constraints in implementing sustainable technologies, and regulatory complexities that vary across different regions or jurisdictions. Moreover, the dynamic nature of maritime trade, characterized by evolving vessel technologies and shifting trade patterns, poses an ongoing challenge in maintaining sustainable practices aligned with these changes.

### **2.1.2 Social sustainability**

Social sustainability at SMSPs is a multifaceted endeavor encompassing a range of initiatives to enhance the well-being of communities, workers, and stakeholders impacted by port activities (Alamouch et al., 2021; Argyriou and Tsoutsos, 2023). However, social sustainability at SMSPs faces challenges distinct from larger ports, including limited financial resources, smaller operational capacities, and fewer opportunities for diverse community engagement. These ports often confront issues of balancing economic growth with preserving community values, cultural heritage, and social cohesion. Overcoming these challenges requires a tailored approach that integrates the unique socio-economic context of the local community, collaborative partnerships with stakeholders, and a commitment to inclusive practices.

### **2.1.3 Economic sustainability**

Economic sustainability at SMSPs revolves around ensuring their long-term viability, competitiveness, and contribution to the regional economy while managing resources efficiently. These ports are vital economic drivers, providing employment opportunities, facilitating trade, and



supporting local businesses. Economic sustainability initiatives at SMSPs often focus on optimizing operational efficiency, investing in infrastructure development, and exploring innovative technologies to enhance productivity (Barona et al., 2023). However, achieving economic sustainability at SMSPs faces challenges, including limited financial resources for infrastructure upgrades and technology investments, competition from larger ports, and fluctuating market demands. These ports often encounter constraints in accessing funding for expansion projects or implementing modernization initiatives. Moreover, they may need help with scalability issues and achieving economies of scale compared to larger counterparts. Overcoming these challenges requires strategic planning, innovative business models, and collaboration among port authorities, private sector partners, and governmental agencies to identify growth opportunities, streamline operations, and leverage regional strengths. Emphasizing economic sustainability allows small and medium ports to adapt to market changes, enhance their market position, and contribute significantly to the economic vitality of their regions while ensuring long-term viability in a competitive maritime landscape.

## **2.2 Historical background to the concept of sustainable development**

The historical background to the concept of sustainable development is described below:

- Sustainable development emerged at the Stockholm Conference on the Human Environment in 1972. There, for the first time, experts in the field referred to links between the environment and development. At the same conference, the United Nations Environmental Program (UNEP) was created to guide and encourage cooperation to protect the environment by inspiring, informing, and enabling MS to improve their quality of life without undermining the quality of life of future generations (Klarin, 2018).
- In 1980, the International Union for Conservation of Nature and Natural Resources presented the World Conservation Strategy and mentioned Sustainable Development. However, this term is more closely attributed to the concept of ecological sustainability, which mainly refers to the existence of the environmental conditions necessary to support human life at a certain level of well-being through future generations (Holden et al., 2014)
- The intensification of initiatives for environmental protection and strong concerns about the extent and impact of economic growth led in 1983 to the UN's creation of the World Commission on the Environment and Development-W.C.E.D. Its work aimed to write a report on

measures and recommendations for environmental protection in the development context to be implemented after 2000 (Roger-Monzó et al., 2023).

➤ In 1987, the World Commission on Environment and Development, building on the Stockholm Conference, published the Brundtland Report entitled *Our Common Future* (Bâc, 2008). For the first time, this report defined the term 'Sustainable Development' as follows: "It is a development that meets the needs of the present without undermining the ability of future generations to meet their own needs" (Malešević-Perović and Ćorić, 2024).

➤ In June 1992, the United Nations convened the 2nd United Nations Conference on Environment and Development in Rio de Janeiro. At this conference, the international community understood and fully accepted the contribution of the environment as a value in itself to human well-being and integrated development (Wang and Tsai, 2023).

➤ Article 2 of the Amsterdam Treaty (1997) refers to "a harmonious balanced and sustainable development of economic activities" (European Communities, 1999). Thus, sustainable development ceased to be seen as an exclusively environmental concept. It was recognized that there should be a close link between economic growth, social cohesion, and environmental protection in the context of the EU's sustainable development strategy (van Vuuren et al., 2015).

➤ A few years later, in 2005, the UN World Summit recognized three pillars on which sustainability rests: economic, environmental, and social (Murthy and Kurtz, 2016)

➤ In 2012, the United Nations World Conference on Sustainable Development (UNCSD), also known as "Rio+20", was held in Rio as a follow-up to the Rio and Johannesburg Conferences. Taking stock of progress over the last 20 years and redefining sustainable development policies globally was the subject of the conference's work (van Vuuren et al., 2015).

➤ In September 2015, world leaders adopted the UN document "Changing our World: the 2030 Agenda for Sustainable Development", which sets out a set of Sustainable Development Goals (SDGs) to end poverty, protect the planet, ensure the promotion of human rights, and guarantee prosperity for all. Adopting this Agenda represents a historic shift toward a new direction where economic, social, and environmental differences are addressed universally and integrated (Weiland et al., 2021).

➤ The European Union (EU) recognized the need to strengthen its climate ambition. In December 2019, the European Commission announced the European Green Deal (EGD) as the EU's new development strategy for the next decade. It is a roadmap that will guide European policy

for the coming years, with the ultimate goal of achieving climate neutrality by 2050. This goal of reducing greenhouse gas (GHG) emissions requires the restructuring and reshaping of the entire economy and society (Hereu-Morales et al., 2024).

➤ A few months later, to fulfill this ambition, the European Commission announced the new EU Biodiversity Strategy for 2030, subtitled "Bringing Nature back to Life", and the new Action Plan for the Circular Economy for a cleaner and more competitive Europe. The structure of the latest green architecture seeks to transform the EU into a fair and prosperous society with a modern, competitive, and resource-efficient (circular) economy with zero GHG emissions. More specifically, the text of the Green Deal sets out three key pillars: i) to make Europe a climate-neutral continent by 2050; ii) to protect, preserve, and enhance natural capital and protect the health and well-being of citizens from environmental risks and impacts; iii) to ensure that the green transition is equitable and inclusive (Hermoso et al., 2022)

➤ Following on from the above and to define a coherent framework to help transform society and the economy, the European Commission on 14 July 2021 presented the interim "Fit for 55%" package, which will be the starting point for a two-year cycle of policy negotiations, with a phased implementation in 2023 (Caliskan, 2022). The Fit-for-55 strategy ensures a fair and socially equitable transition to green growth, maintains and strengthens the innovation and competitiveness of businesses, industries, and operators, and consolidates the European Union's position as a global leader in tackling and combating climate change. In the above context, services and industries, such as ports and shipping, should take into account in their development plan the green transition for their future activities and adopt precisely a green growth model based on the use of clean energy sources for their operations, to create a net green footprint.

### **2.3 Sustainable Development Goals (SDGs)**

In 2000, the Member States of the United Nations agreed on the so-called Millennium Development Goals to guide global development. The Millennium Development Goals targeted eight areas: poverty, education, gender equality, child mortality, maternal health, disease, environment, and international cooperation. However, new global challenges have emerged, and social and environmental problems have arisen (de Jong and Vijge, 2021). Thus, since the UN World Conference in Rio in 2012, a process has been initiated to set new global goals to address the growing challenges of Sustainable Development and follow the Millennium Development

Goals. In 2013, a working group involving the private sector was established, unlike the Millennium Development Goals (set in 2020). Thus, besides the UN agencies, this working group includes many private sector representatives, including leading business organizations. In September 2015, an agreement was signed on 17 SDGs where each goal presents sub-specific targets (Caliskan, 2022). In total, 169 specific targets are set, and thousands of indicators are defined to assess the achievement of the targets (Wang et al., 2020).

The 17 main SDGs are presented in the graph below:



**Figure 2.1.** Sustainable Development Goals

At the EU level, the SDGs are a central component of the new EU Green Deal, which also provides the framework for the pandemic recovery programs towards a "build back better and greener" recovery for all Member States. In this context, sustainable maritime transport is an essential factor for most SDGs, as described below:

**SDG 14 Conserve and sustainably use oceans, seas, and marine resources for sustainable development.**

SDG 14 is the predominant sustainable development goal related to shipping. International shipping takes measures to improve safety, secure international shipping, and prevent pollution from ships (He et al., 2021). SDG 14 seeks to sustainably conserve and use the oceans, seas, and

marine resources. As such, it aims to prevent and reduce marine pollution of all kinds, minimize and address the impacts of ocean acidification, and regulate fisheries, among other objectives.

**SDG 1 End poverty in all its forms / SDG 2 End hunger, achieve food security, improve nutrition, and promote sustainable agriculture / SDG 16 Promote peace and integrated partnerships for sustainable development, provide access to justice for all, and effective institutions at all levels.**

SDGs 1, 2, and 16 also relate to shipping (Ali Akyar Bandirma Onyedi Eylül Üniversitesi, 2019). As the most cost-effective and fuel-efficient way to transport goods, maritime transport is at the heart of global trade and globalization. Worldwide trade and maritime transport sustain economic growth and spread prosperity worldwide. Improving access to primary materials, goods, and products is expected to lift millions of people out of poverty and contribute to achieving SDGs 1 and 2.

**SDG 4 Ensures quality education and enhances opportunities for lifelong learning for all. SDG 5 aims to achieve gender equality and empower all women and girls. SDG 8 Promotes secure and sustainable economic growth, professional and productive employment, and work rehabilitation for all.**

SDGs 4, 5, and 8 are predominantly shipping-related SDGs (Caliskan, 2022). International shipping and related industries depend on the skills of seafarers and shore-based personnel to support ship operations. The maritime Community contributes to the quality of life, particularly in developing countries, by employing 1.5 million seafarers, thereby directly enhancing the economic prosperity of local communities. The safety of life at sea, the protection of the marine environment, and the efficient movement of world trade depend on the professionalism and competence of seafarers.

**SDG 7 Ensure access to affordable, reliable, sustainable, and modern energy for all / SDG 13 Take action to combat climate change and its impacts.**

The shipping industry could achieve this target by providing even more sustainable shipping services based on solar, tidal, wind, wave, and biomass energy (Liu and Yuan, 2023). In addition, using renewable energy solutions in its operations, such as biofuels, hydrogen, solar, and wind energy, could improve the energy efficiency of both ports and ships.

## 2.4 Typologies of ports due to their size and operations

A port infrastructure differs from that of others due to various features. Some of them are their size, the ships they serve, their management body, and their geographical location. Thus, according to Decision No 1346/2001/EC of the European Parliament, we can classify the ports into the following three categories (Ali Akyar Bandirma Onyedi Eylül Üniversitesi, 2019).

a. international seaports: ports with a total annual traffic volume of not less than 1,5 million tonnes of freight or 200.000 passengers which are connected with the overland elements of the trans-European transport network and, therefore, play a significant role in international maritime transport;

b. Community seaports, not included in category A: these ports have a total annual traffic volume of not less than 0,5 million tonnes of freight or between 100.000 and 199.999 passengers, are connected with the overland elements of the trans-European transport network and are equipped with the necessary transshipment facilities for short-distance sea shipping;

c. Regional ports: These ports do not meet the criteria of categories A and B but are situated on the island, peripheral, or outermost regions, interconnecting such regions by sea and connecting them with the central regions of the Community.

**Table 2.1.** Port categories

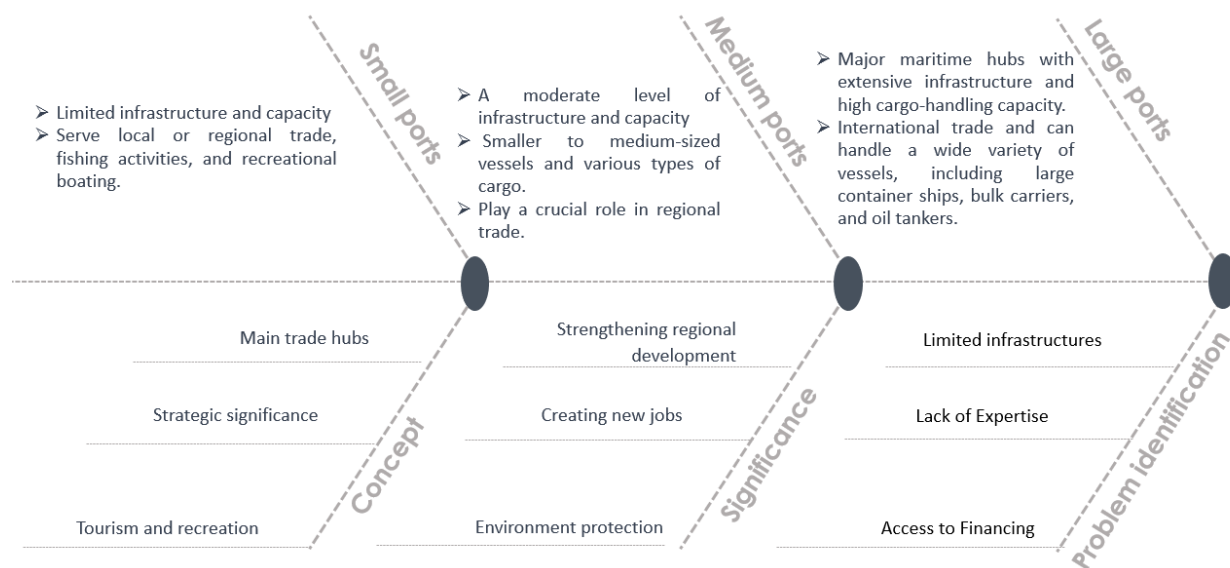
International ports	National ports	Local ports
Large sized	Medium-sized	Small sized
ports with a total annual traffic volume of not less than 1,5 million tonnes of freight or 200.000 passengers	these ports have a yearly total traffic volume of not less than 0,5 million tonnes of cargo or between 100.000 and 199.999 passengers	these ports do not meet the criteria of categories large or medium

For this research, ports would be classified into different types based on their size: large, medium, and small (Figure 2.2)

a. Small ports: These ports can range in size and amenities but usually serve the needs of a smaller area. Often found in or near coastal regions or smaller towns, these communities may focus on a single industry, fishing, or tourism.

b. Medium ports: The second category, medium-sized ports, are larger and more technologically advanced than small ports but may need the capacity and capabilities of large ports. Warehouses, container terminals, and break-bulk cargo facilities are all regular features at these ports. Some medium-sized ports can accept larger vessels and have more sophisticated cargo-handling equipment like cranes and forklifts. Passenger terminals for ferries and cruise ships may also be available at medium-sized ports. Medium-sized ports can serve as regional transportation centers and link to larger ports for international cargo.

c. Large ports: These ports are significant international gateways for marine trade. Container terminals, bulk cargo facilities, and specialty facilities for processing automobiles, cattle, and other sorts of cargo are only some of the cargo-handling facilities they offer. Big ports often have sophisticated port equipment like gantry cranes and automated container-handling systems. The largest ships in the world can dock there, and they can handle a high volume of goods. Big ports are typically situated in or near major cities and are linked to other modes of transportation, such as roads, rails, and airfields.



**Figure 2.2.** Categorization of ports



## **2.5 Problems**

Sustainable planning for SMSPs is essential to ensure their long-term viability while minimizing negative environmental and social impacts. However, some fundamental problems and challenges are associated with sustainable planning for small and medium ports.

### **2.5.1 Limited resources**

Limited resources pose a significant challenge to sustainable planning for small and medium ports. These ports often need help securing the funding and expertise required to implement environmentally friendly technologies and practices. As they face budget constraints and resource limitations, finding cost-effective solutions that balance economic development with environmental and social responsibility becomes increasingly difficult (Kuznetsov et al., 2015). Sustainable planning initiatives, such as upgrading infrastructure for improved efficiency or mitigating environmental impacts, may be delayed due to these resource constraints, ultimately hindering the ports' ability to achieve long-term sustainability goals.

### **2.5.2 Limited space**

Limited space presents a significant challenge in sustainable planning for small and medium ports. These ports often find themselves constrained by their physical footprint, with limited available land for expansion or implementing environmentally friendly infrastructure (Ding et al., 2023a). This spatial limitation can hinder efforts to enhance transportation efficiency or implement sustainable technologies like shore power for docked vessels or green buffer zones to mitigate environmental impacts. Balancing the need for economic growth with responsible land use and environmental stewardship becomes a complex puzzle in the face of limited space, requiring innovative solutions and careful spatial planning to ensure the long-term sustainability of these vital maritime hubs.

### **2.5.3 Limited access to technology and expertise**

Limited access to technology and expertise is a significant problem in the sustainable planning of small and medium-sized ports. These ports often need more financial resources and specialized knowledge to adopt and implement cutting-edge technologies and sustainable practices. Access to the latest innovations in energy efficiency, emissions reduction, data analytics, and logistics



optimization is necessary to minimize their environmental footprint and improve operational efficiency. Furthermore, the need for more skilled personnel with expertise in sustainable port management can hinder efforts to develop and execute long-term sustainability strategies. Addressing this challenge requires collaborative efforts among industry stakeholders, government agencies, and educational institutions to provide technology transfer, training, and support to empower small and medium-sized ports to embrace sustainability practices effectively.

#### **2.5.4 Lack of data**

The need for comprehensive and up-to-date data represents a significant challenge for sustainable planning in SMSPs. Accurate and detailed information regarding environmental conditions, cargo flows, energy consumption, and other critical factors is essential for making informed decisions that promote sustainability. However, smaller ports often need more support in data collection and management resources, leading to gaps in their understanding of environmental impacts and operational inefficiencies (Almeida, 2023). With robust data, it becomes easier to develop and implement targeted sustainability strategies, monitor progress, and measure the effectiveness of initiatives, hindering their ability to optimize operations and minimize negative environmental and social consequences. Addressing this issue requires investments in data collection and analysis tools and collaboration with relevant stakeholders to improve data-sharing practices and ensure that small and medium-sized ports have access to the information necessary for informed and sustainable planning.

#### **2.5.5 Inadequate infrastructure**

Inadequate infrastructure is a significant hurdle in the sustainable planning of small and medium-sized ports. Many of these ports must grapple with ageing or insufficient infrastructure, which can impede their ability to meet modern environmental and efficiency standards. Outdated berths, inadequate cargo handling facilities, and limited road connections can lead to congestion, increased emissions, and operational inefficiencies, making it challenging to implement sustainable practices (Munim and Schramm, 2018). Upgrading infrastructure to accommodate larger vessels, improve cargo handling efficiency, and reduce environmental impacts often requires substantial investment, which may be beyond the financial capacity of smaller ports. Addressing this issue necessitates strategic planning, securing funding, and collaborating with

public and private stakeholders to revitalize and modernize port infrastructure, enabling these ports to embrace sustainable practices and remain competitive in an evolving global shipping industry.

#### **2.5.6 Lack of awareness and education**

The need for more awareness and education about sustainable planning represents a critical challenge for small and medium-sized ports (Othman et al., 2022). Often, these ports operate in regions where awareness of environmental and social sustainability practices may be limited. With a well-informed and educated workforce, it becomes easier to recognize the importance of sustainability and implement meaningful initiatives. Moreover, awareness can help collaboration with stakeholders and communities, as it may result in misconceptions about the port's environmental and social impact. Overcoming this challenge requires investing in educational programs and training to raise awareness among port staff, management, and local communities about the benefits of sustainable planning. It also involves fostering a culture of sustainability within the organization, where environmentally and socially responsible practices are integrated into daily operations, ultimately driving positive change and long-term sustainability for these ports.

In conclusion, sustainable planning for SMSPs faces many complex challenges that demand careful consideration and proactive solutions. While crucial to regional economies, these ports grapple with limited resources, inadequate infrastructure, and a need for more awareness about sustainable practices. Balancing economic growth with environmental and social responsibility is delicate for these ports, especially when access to technology, funding, and expertise is constrained. Engaging stakeholders and local communities effectively and addressing climate change resilience and resource efficiency issues further compound the challenges. Despite these obstacles, sustainable planning for small and medium-sized ports is not only possible but essential for their long-term viability. Overcoming these challenges requires collaborative efforts involving public and private stakeholders, investment in infrastructure and education, and a steadfast commitment to fostering sustainability as a fundamental guiding principle for these vital maritime hubs.

## **2.6 Importance of ports**

### **2.6.1 Importance of SMSPs due to sustainable factors**

From antiquity to modern times, trade by sea has undoubtedly been extremely important for the evolution of humanity itself, since through it, the transport of vast quantities of goods necessary for it is achieved, as well as the development of the economies of any state, since as it is widely known 85% of world trade is transported by sea. For Europe, where this research will focus, the figure is nearly 90% of total trade. The global economy is mainly based on international trade, combined with the increasing participation of countries in global transport systems, making trade infrastructure of paramount importance for economic development. In addition, the significant contribution of ports worldwide lies in the effective operation and maintenance of the global supply chain, where only some of the above could be achieved with their development and operation. In particular, ports are part of the main axis that moves almost the entire world trade. Therefore, the importance of ports for the world economy is crucial when one considers the amount of international trade that occurs or is connected by the sea.

The importance of small/medium ports can be explained as described below:

#### **a. Trade Facilitation**

Small and medium-sized ports are instrumental in trade facilitation, often serving as crucial gateways for regional and local economies (Meyer, 2021). While they may not handle the immense cargo volumes of larger ports, they specialize in providing efficient and accessible trade solutions. These ports offer businesses in remote areas a direct connection to global markets, reducing transportation costs and increasing market access. By accommodating smaller vessels and catering to niche industries, they enable the smooth flow of goods, supporting local enterprises and international trade.

#### **b. Job Creation**

Small and medium-sized ports are vital engines of job creation, particularly in regions where they are situated. These ports provide employment opportunities across diverse roles, from dockworkers and customs officials to administrative staff. Small and medium ports generate stable incomes for workers and contribute to long-term economic development by attracting businesses, fostering innovation, and enhancing the overall socio-economic fabric of their regions (Hidalgo-Gallego and Núñez-Sánchez, 2023). Moreover, their influence extends beyond direct employment, as they stimulate ancillary industries and support services such as transportation, manufacturing,

and tourism. This amplifies their job creation impact, bolstering local economies and improving the livelihoods of communities in their proximity.

c. Economic Growth

Small and medium-sized ports play a vital role in fostering economic growth. They offer accessibility to remote areas and facilitate trade for local industries, often specializing in specific agriculture, fishing, or tourism sectors (Lonza and Marolda, 2016). By providing efficient transportation options, they reduce logistical costs, attract investments, and create jobs, contributing significantly to the economic well-being of their surrounding communities. Furthermore, their adaptability and personalized services make them key enablers of local economic diversification and sustainability, showcasing their indispensable role in driving economic growth on both regional and national scales.

d. Energy Supply

SMSPs, while often overshadowed by their larger counterparts, play a vital role in ensuring energy supply resilience (Buonomano et al., 2023). These ports are strategically positioned to facilitate the importing and distributing energy resources, including oil, natural gas, and coal, to local and regional markets. They provide access points for transporting these critical energy commodities, ensuring a stable supply for industries, businesses, and households. Their contribution to energy supply security is essential for sustaining economic activities, supporting industrial processes, and meeting the energy needs of communities in diverse geographical regions.

e. National Security

Small and medium-sized ports play a critical role in enhancing national security. These ports are integral components of a nation's maritime infrastructure, and their security is paramount to safeguarding against various threats, including terrorism, smuggling, and illicit trafficking (Carella et al., 2024). By fortifying the security of small and medium-sized ports, nations strengthen their overall maritime security posture and contribute to the safety and resilience of their economies and communities.

f. Environment

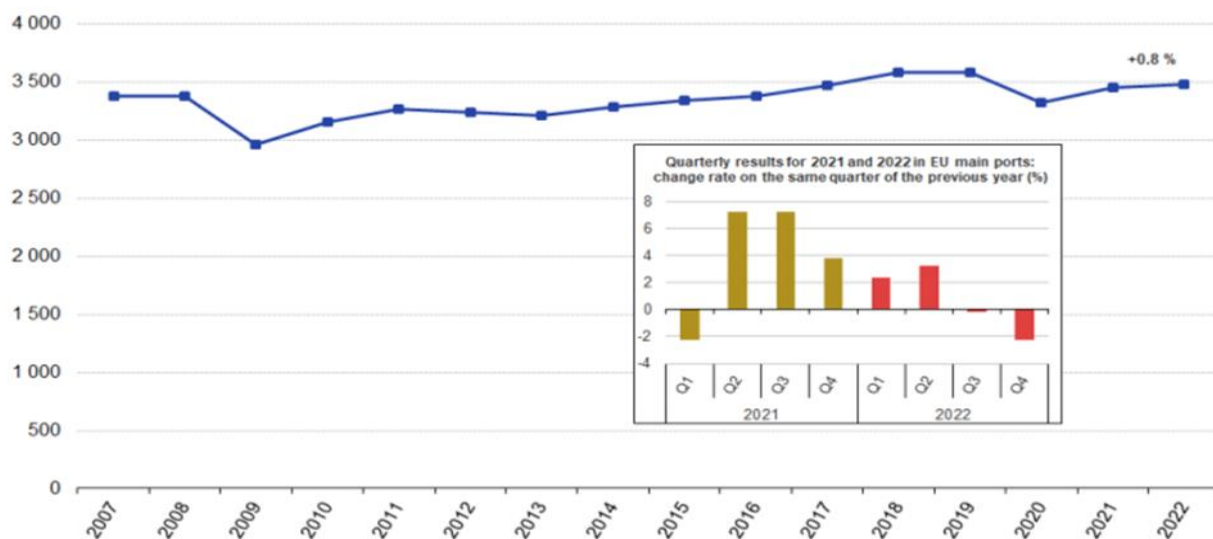
Port operations directly influence the environmental impact of shipping and trade, making them essential in the global effort to reduce emissions, protect natural ecosystems, and advance sustainability (Damman and Steen, 2021). Environmentally conscious port operations often implement measures to control and mitigate potential pollutants from entering the air and water.

These measures encompass the use of cleaner fuels and technologies, dust suppression systems, and stringent regulations on emissions from port machinery and vessels. By adopting eco-friendly practices and adhering to rigorous environmental standards, SMSPs play a crucial role in preserving natural habitats and safeguarding marine ecosystems.

## 2.6.2 Importance of ports due to their geographical position

### 2.6.2.1. Importance of ports in the EU

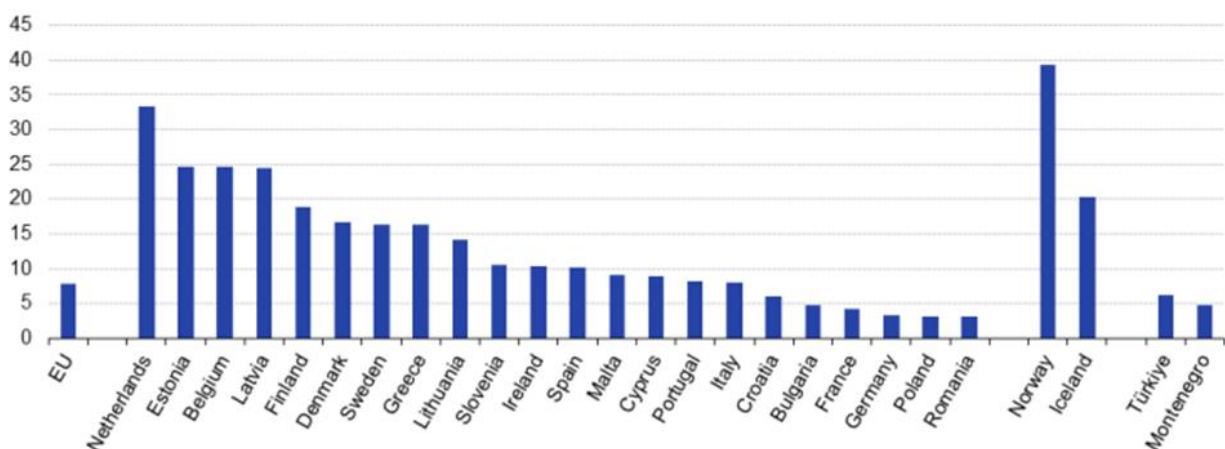
The estimated total gross weight of goods managed at European Union ports in 2022 reached 3.5 billion tonnes, showing a slight increase of 0.8% compared to the previous year. Despite the recovery, the 2022 levels remain slightly below those observed in 2018. The freight activity in EU ports exhibited a positive trend from 2014 until the downturn in 2020, indicating a gradual path to recovery after the economic crisis in 2009, as illustrated in Figure 2.3. This uptick follows a significant decline in 2020, likely attributable to the impact of the COVID-19 pandemic and subsequent global and EU-specific restrictions.



**Figure 2.3:** Gross weight of seaborne freight handled in all ports, EU, 2007-2022 (million tonnes)

In 2022, the Netherlands retained its status as the foremost country for maritime freight transport in Europe, with Rotterdam, Antwerp-Bruges, Hamburg, Amsterdam, Algeciras, and Marseille maintaining their positions as the top seven freight ports in the EU. The per-capita ratio of seaborne freight varied among EU Member States, ranging from 33.3 tonnes per inhabitant in the Netherlands to 3.2 tonnes per inhabitant in Poland and Romania. The EU average stood at 7.8

tonnes per inhabitant. Notably, among countries reporting maritime data to Eurostat, Norway recorded the highest ratio at 39.4 tonnes per inhabitant in 2022, as depicted in Figure 2.4.



**Figure 2.4.** Gross weight seaborne handled in all ports, 2022 (tonnes per capita)

In 2022, Rotterdam, Antwerp, and Hamburg, all situated along the North Sea coast, maintained their positions as the top three ports in the EU. This was evident in the gross weight of goods handled and the volume of containers processed within these ports. The 20 most significant cargo ports collectively handled half (50.2%) of the total tonnage of goods in EU ports for the year. Rotterdam, the largest European port in the Netherlands, contributed 12.3% to the overall tonnage handled in EU ports (refer to Figure 7).

The composition of the seven largest cargo ports in the EU remained consistent between 2021 and 2022. Among the top 20 EU ports, ten experienced a decline in the volume of goods handled in 2022 compared to the previous year. Notably, Piraeus (-8.8%), Bremerhaven (-8.6%), Valencia (-7.1%), and Hamburg (-7.0%) reported the most substantial decreases. Conversely, Gdańsk recorded the highest growth at +40.3%, followed by Cartagena (+17.3%), Constanța (+15.2%), and 'Zeeland Seaports' (+11.0%).

### 2.6.2.2. Importance of ports in the Mediterranean

Throughout millennia, the ports of the Mediterranean have been instrumental in shaping the course of human history, enabling cultural exchanges and trade between diverse civilizations. They have served as gateways for spices, textiles, precious metals, and other goods, fostering economic prosperity and contributing to the development of advanced societies. Their enduring legacy

continues today as they handle modern cargo and provide essential transportation links for the global economy.

Ports in the Mediterranean are crucial for regional and global trade. Their strategic location at the intersection of Europe, Asia, and Africa positions them as vital hubs for the movement of goods, fostering economic growth and stability. These ports play a pivotal role in facilitating the exchange of various commodities, from consumer goods to raw materials and energy resources, making them indispensable for supply chain networks and international commerce.

In addition to their economic impact, ports in the Mediterranean also hold geopolitical significance. Their presence and operation influence regional dynamics, trade partnerships, and diplomatic relations among countries bordering the Mediterranean Sea. The ability to control or gain access to these ports has been a strategic objective for nations throughout history, underscoring their enduring importance in shaping geopolitical strategies and regional stability. As a result, the Mediterranean ports remain a focal point for policymakers and global stakeholders in ensuring the smooth flow of goods and fostering international cooperation.

### **2.6.2.3. Importance of ports in Greece**

With its extensive coastline and strategic geographical location, Greece boasts numerous ports that have played a pivotal role in shaping its history and economy. These ports are vital gateways connecting Greece to the Mediterranean and beyond, facilitating trade, tourism, and cultural exchanges. The significance of Greek ports extends beyond mere economic considerations; they are a testament to the nation's maritime heritage and influence on global affairs.

Firstly, the ports of Greece serve as crucial hubs for international trade. With a rich history of seafaring and maritime commerce, Greece's ports have facilitated the exchange of goods and services between Europe, Asia, and Africa. Piraeus, the main port of Athens, stands out as one of the Mediterranean's busiest and most important ports, serving as a gateway for goods entering and leaving Europe. The efficient functioning of these ports is fundamental to Greece's economic prosperity, as they contribute substantially to the country's trade balance and overall economic development.

Secondly, Greece's ports are essential for the flourishing tourism industry. The country's picturesque islands, historical sites, and vibrant culture attract millions of tourists annually. Acting as entry points for cruise ships and ferries, the ports are crucial in welcoming visitors and



facilitating their exploration of Greece's diverse landscapes and cultural treasures. From the port of Santorini with its stunning views to the historic port of Heraklion (HER) in Crete, these maritime gateways contribute significantly to Greece's reputation as a premier tourist destination.

Thirdly, the strategic location of Greek ports holds geopolitical significance. Greece's proximity to major shipping routes and its position at the crossroads of Europe, Asia, and Africa make its ports critical assets for global trade and naval operations. This strategic importance has historically shaped the nation's role in international affairs and led to Greece's crucial role in maritime security. The country's participation in various naval alliances and organizations underscores the geopolitical value attached to its ports.

Lastly, Greek ports are integral to preserving the nation's maritime traditions and cultural identity. The naval history of Greece is deeply ingrained in its cultural fabric, and the ports stand as living monuments to this heritage. The bustling harbors, fishing communities, and maritime activities reflect a connection to the sea that has been central to Greek identity for centuries. Ports like Thessaloniki and Patras not only facilitate modern trade but also serve as reminders of Greece's enduring maritime legacy.

In conclusion, the importance of ports in Greece extends far beyond their economic contributions. They are the nation's lifeblood, connecting it to the world, supporting its economy, and preserving its rich maritime history and culture. As Greece continues to navigate the challenges and opportunities of the modern world, its ports remain steadfast pillars of strength, ensuring its continued relevance on the global stage.

## **2.7 Competent bodies/organizations in the context of sustainable development**

In the context of port sustainable development, the following competent bodies and organizations have played and are still playing important roles:

- a. At an international level, the main organization in the context of sustainable development is the International Maritime Organisation (IMO). Since its establishment in 1948, through the adoption of numerous conventions and protocols, it has been active in promoting the safety of international shipping and protecting the marine environment from pollution caused by human activity and ships. Through the organization, member countries, society, and the port industry work together to help shape a green economy, including energy efficiency of ships, maritime education,



maritime safety, maritime infrastructure development, and the efficient management of all types of cargo, which include the most dangerous and harmful cargoes (Gonzalez Aregall et al., 2018).

b. At the European level, the EU, through its institutions and in cooperation with IMO, carries out numerous legal interventions related to environmental issues for the port industry.

c. In addition, various regional organizations, established either through the United Nations Environment Programme or independently of it, are trying to shape the development of coastal states and their ports through coordinated actions within a sustainability and green development framework. An illustrative example is the creation of the European Sea Ports Organisation (ESPO) in 1993. This organization helps European policymakers better understand the role and importance of port authorities based on extensive knowledge of the sector and reliable information and data.

d. The European Sustainable Shipping Forum (ESSF) provides a platform for structural dialogue, technical knowledge exchange, cooperation, and coordination between the Commission, Member State authorities, and maritime transport stakeholders on issues related to the sustainability and competitiveness of EU maritime transport (Corres, 2014). The ESSF has been operational since 2013 and has become an effective tool for engaging and exchanging views on various environmental issues in maritime transport, such as air pollution and GHG emissions. The ESSF has prepared the ground for numerous coordinated submissions to the IMO or the International Organization for Standardization.

e. The World Association for Waterborne Transport Infrastructure (PIANC) published in 2014 its report "Sustainable Ports - A Guide for Port Authorities" (Alamouch et al., 2021). The PIANC report supplies tools and guidance that show how proactive environmental measures and strategies can contribute to obtaining consent for future operations and developments, how opportunities can be created through their own initiatives, and how green growth can be realized. Respectively, the report advocates the shift of thinking towards a proactive "ports and nature/environment" approach, starting from a long-term vision perspective.

f. By Article 22 of Regulation (EC) No 1406/2002, as amended, establishing a European Maritime Safety Agency (EMSA) contributes to a safer and more secure maritime environment and to the increased ability of Member States to prevent and respond to marine pollution by pursuing activities and objectives that correspond to the needs of the EU in the area.

## **2.8 Sustainable/green ports**

According to the American Association of Port Authorities (AAPA), port sustainability refers to the strategies and activities that meet the current and future needs of ports while protecting and conserving human and natural resources (Lawer et al., 2019). These ports aim to reduce their negative impact on the environment and local communities while promoting economic growth and social equity. They implement various strategies and practices to achieve these goals, such as reducing emissions and waste, using renewable energy sources, promoting sustainable transport, and working with stakeholders to promote sustainability. Another critical aspect of sustainable ports is the promotion of sustainable transport. This includes promoting the use of low-emission modes of transportation, such as electric vehicles, optimizing freight movement, and reducing waste.

A broader literature recognizes the complexity of port transitions towards sustainability and the need to involve many party population individuals (Cheon et al., 2017). This includes developing strategies to mitigate the negative impacts of port operations on nearby communities, such as noise and air pollution, and working with those communities to promote economic development and job creation. According to (Davarzani et al., 2016), practical engagement with the idea of "green" ports began to prevail in European and North American ports. Pioneering ports in Europe, such as those of Rotterdam (Netherlands) and Antwerp (Belgium), receive the "green" designation based on the adoption of a set of measures aimed at low carbon dioxide emissions or improving air quality, energy efficiency, or the use of renewable energy sources, sustainable mobility or reducing the impact of climate change, which are the main green measures.

## **2.9 Stakeholders in a port**

One key challenge in achieving sustainability in ports is balancing stakeholders' competing interests and priorities. Some stakeholders may prioritize economic development, while others may prioritize environmental protection or social responsibility. Sustainable port development requires the cooperation and collaboration of many stakeholders, including port authorities, shipping lines, cargo owners, terminal managers, environmental groups, local communities, and government agencies.

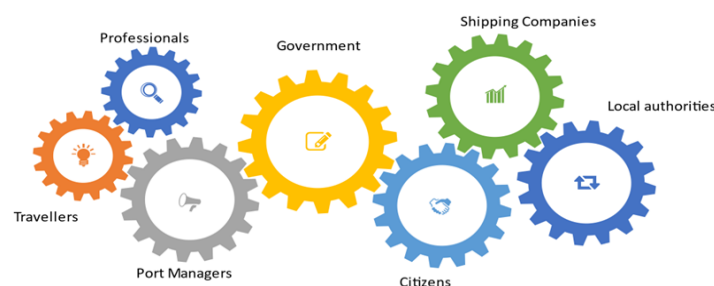
Effective stakeholder engagement for sustainability involves building strong relationships and partnerships with stakeholders. This may include engaging stakeholders in developing

sustainability policies and initiatives, providing opportunities for feedback and input, and working with stakeholders to create innovative solutions that balance economic, environmental, and social considerations.

Stakeholders also play a critical role in monitoring and evaluating port sustainability performance. Stakeholders can provide feedback on sustainability initiatives and monitor the implementation of sustainability policies and practices. This can help ensure that sustainability efforts are effective and meet stakeholder needs and expectations.

Below, port stakeholders are described analytically:

1. Port authorities: They are the organizations responsible for managing and regulating port operations. They are responsible for ensuring the safety and security of the port, maintaining infrastructure and facilities, and enforcing regulations and policies.
2. Port operators: These companies lease facilities in the port to operate their businesses, such as shipping lines, terminal operators, and logistics companies.
3. Port workers: These are the people directly or indirectly employed by the port, including dock workers, truckers, truck drivers, and administrative staff.
4. Shipping lines: These companies transport goods to and from the port by sea. They are critical stakeholders as their activities directly impact the cargo volume passing through the port.
5. Customers and suppliers: These companies use the port to import or export goods.
6. Local communities: The residents and businesses in the port area. They are affected by noise, pollution, and traffic associated with port operations, and their interests include environmental protection, public health, and safety.
7. Government agencies: These are the regulatory bodies responsible for overseeing port operations and enforcing environmental, health, and safety regulations. They are critical in ensuring that ports operate by laws and regulations.



**Figure 2.5.** Main stakeholders of ports

## **Chapter 3- Sustainable Solutions for Small/Medium Ports: A Guide to Efficient and Effective Planning**

### **3.1 Introduction**

Over time, a new environment of activity for ports has been created. This is quite competitive, with a large capacity, bringing about significant structural changes (I. Argyriou et al., 2022). Initially, the phenomenon of globalization of markets and, in general, the substantial growth in international trade, with the high demand for products, such as from various Asian countries to the rest of the world, as well as each other, in combination with both the modern needs of consumers and the development of combined transport (land, road, and sea) have resulted in significant investment in port infrastructure and superstructures (Fan et al., 2022). At the same time, there have been changes due to rapid developments in technology, such as various information systems and technological changes to the ships themselves, such as their size, to make fewer trips by transporting more cargo, as well as specialization in specific markets, so that they can accept modern ships and new products (Hsu et al., 2023). As a result, ports are now complex enterprises with quite specialized modes of operation, requiring their continuous development and finding enough capital to create the right conditions to provide high-quality services in combination with an attractive package (cost savings, speed of transport, and cargo security) that responds to the requirements of the trade (Baccelli and Morino, 2020).

Sustainability is becoming an increasingly significant aspect of port effectiveness, and SMSPs are no exception. SMSPs are essential for regional and local economies since they facilitate commerce and transport (O'Connor et al., 2023). In contrast, port operations can harm the environment and local population through air and water pollution, habitat destruction, and increased noise and traffic (Alamouh et al., 2022). Sustainability planning is essential to maintain the long-term survival of SMSPs and advance sustainable development. By adopting a proactive sustainability posture, SMSPs can enhance their operations, minimize their environmental impact, and contribute to a more sustainable future. Numerous factors necessitate sustainability port planning, such as the worldwide trend toward sustainability, the increasing public awareness of the environmental impact of port activities, and the need to comply with legal requirements (Formentin, 2021). Nevertheless, many ports face formidable obstacles, such as limited resources, congestion, and air and water pollution.

Moreover, sustainability planning for SMSPs can provide significant social, community, environmental, and economic benefits. SMSPs can improve the quality of life for nearby people by improving working conditions for port workers and supporting local communities. This can

result in increased community engagement and support for the port and a positive reputation as a responsible and socially conscious entity.

Much research has been carried out to plan the sustainability of large ports. However, sustainable planning differs between small and large ports, as they face different challenges and obstacles. Some of these differences focus on the following issues: stakeholder engagement, funding, technical expertise, and technological implementation (Cheon et al., 2018; Gerlitz and Meyer, 2021). Furthermore, while several studies have focused on individual initiative solutions to sustainability problems (Twrdy and Zanne, 2020), the literature must consider the sustainability-oriented planning approach for SMSPs.

The complexity of the sustainable planning of SMSPs over time has attracted the interest of many researchers (Sifakis and Tsoutsos, 2021), as developments and innovations in the field of transport and technology have had a direct impact, affecting and redefining the relationships between ports and the economic, social, and spatial systems to which they belong. The main obstacles to planning a small/medium port's viability are the complexity of how it is administered, financed, and legislated. More specifically, SMSPs face unique challenges when it comes to implementing sustainable planning practices, including:

1. Limited resources: SMSPs often need more financial and personnel resources, making it difficult to invest in sustainable infrastructure and technology;
2. Competition with larger ports: SMSPs often face competition from larger ports, which may offer more attractive amenities and services, making it challenging to attract cargo and shipping businesses;
3. Environmental concerns: SMSPs are often located in environmentally sensitive areas and must consider their operations' impact on the surrounding ecosystem;
4. Ageing infrastructure: SMSPs may have infrastructure that needs to be replaced or upgraded, which can be challenging due to limited resources;
5. Technological challenges: SMSPs may need more access to technology and technical expertise to implement sustainable practices and modernize resources (Brunila et al., 2023);
6. Lack of regulatory support: SMSPs may receive less additional support and funding from government agencies than larger ports, making it easier to implement sustainable practices.

Based on the above-described conditions, this step of the survey aims to present a holistic guide for sustainable planning and development of small and medium ports, addressing the pressing need

for environmental stewardship and economic viability and offering actionable insights for policymakers, port authorities, and stakeholders, to collaboratively navigate the complexities of sustainable port development in an era of heightened environmental awareness.

The ultimate survey's objective was to create a methodological guide that illustrates appropriate steps toward a fairer, more direct, efficient, and innovative phase, using technological developments that will serve as a policy tool for public authorities, stakeholders, and citizens, to ensure a high level of sustainable port facilities in the future. The identification of objectives, goals, and research gaps is simultaneously linked to the primary research questions, which are formulated as follows:

1. How can small and medium-sized ports develop comprehensive and adaptive sustainability plans that address environmental, economic, and social dimensions while considering their unique resource constraints and operational scales?
2. What benefits can small/medium ports derive from sustainable planning?

Innovative planning and management strategies must be implemented considering these ports' unique challenges and opportunities to ensure port sustainability and success. As a result, the proposed guide is an original approach to addressing the challenges of SMSPs. It provides ports with the tools and framework they need to create a sustainable and livable environment that is accessible, affordable, and safe for all by focusing on local conditions, collaboration, and adaptability. Rather than simply replicating existing solutions (plans) from other ports, the proposed methodology aims to create unique approaches to port planning tailored to each SMSP's individual needs and characteristics. More specifically, it encourages community engagement and collaboration, which fosters a sense of pride and ownership among community members, resulting in increased usage and a thriving local economy.

Furthermore, it proposes steps to achieve a balance between economic development and environmental protection through the sharing of best practices among ports. Finally, it is intended to be adaptable and flexible, allowing ports to modify their approaches as conditions change and new challenges emerge. This means that the strategy is constantly evolving, and ports can continue experimenting with new and innovative solutions, learning from their successes and failures and refining their approaches over time.

### 3.2 Literature Review

A thorough literature analysis of small/medium port sustainability planning should seek to consolidate existing research and best practices in this sector and propose areas for future study and action. In recent years, port sustainability planning has changed drastically, reflecting a greater understanding of port operations' environmental and social implications and the rising significance of sustainable practices in the marine sector (Zhao et al., 2021). Developing integrated planning techniques that address a port's interconnected physical, economic, and social components and the surrounding community is an essential research topic in small port sustainability planning (García-Onetti et al., 2021). These techniques strive to identify significant problems and possibilities for sustainability planning and to design comprehensive and integrated plans to address these concerns. For instance, research has investigated the use of systems thinking and integrated coastal management as approaches for sustainable port planning, which take into account the impact of the port on the surrounding environment, economy, and social fabric, as well as identifying interrelated factors that contribute to the sustainability of the port and the community (da Veiga Lima and de Souza, 2022).

Stakeholder involvement and community participation are crucial aspects of SMSPs. Developing sustainable port plans that represent the interests and goals of all stakeholders requires effective communication and collaboration among port officials, local enterprises, environmental groups, and community members (Ignaccolo et al., 2018). This research area has used public forums, stakeholder surveys, and community-based participatory procedures to solicit input and feedback from local citizens and engage the broader community in the sustainability planning process.

In addition, research has investigated the use of innovative and sustainable technologies for the planning and operations of small/medium ports, such as using RES (Quero García et al., 2021), implementing sustainable transportation systems, and adopting GI and land-use practices (Bjerkan and Seter, 2019). Some ports, for instance, have developed wind and solar energy systems to minimize their dependency on fossil fuels and have embraced sustainable mobility systems, such as electric trucks, to lessen the environmental impacts of traveling to the port (Densberger and Bachkar, 2022).

SMSPs are taking a proactive approach to sustainability, recognizing that sustainable operations are an ethical imperative and a strategic business opportunity. Best practices and frameworks such as the United Nations SDGs and the World Ports Sustainability Program guide small ports in their



planning for sustainability. The growing focus on stakeholder engagement and the implementation of specific measures and technologies, such as RES and waste management programs, is helping small/medium ports to reduce their environmental impact and contribute to sustainable development (Gavalas et al., 2022). The potential for digitalization and innovation in the maritime industry to enhance sustainability is also significant and an area to watch for future results in port planning sustainability.

Small/medium ports play a significant role in the global supply chain and frequently act as vital links between local communities and businesses. In contrast, limited resources, access to technical expertise, and stakeholder engagement complicate the implementation of sustainable planning techniques for these ports. From the study of academic surveys, it emerged that there is a significant research gap in sustainable planning for small/medium ports, particularly in areas such as environmental impact assessment, energy efficiency, stakeholder engagement, and best practices, which are described as follows:

### **3.2.1. Environmental Impact Assessment**

Long-term planning requires assessing the possible environmental implications of port growth and operations. This involves examining the environmental effect of maritime activities such as dredging and reclamation and port facility design and function. Long-term planning approaches that limit environmental harm while guaranteeing the port's long-term survival require a complete understanding of the environmental implications of port activities. While considerable research has been conducted in this area (Saengsupavanich, 2011; Taljaard et al., 2021), much of it has focused on larger ports, thus creating a knowledge vacuum about the unique environmental implications of smaller port growth. SMSPs have not been able to analyze the possible environmental effects of their activities and apply sustainable planning techniques that are appropriate for their circumstances.

### **3.2.2. Energy Efficiency**

Another crucial part of sustainable design is energy efficiency, which may lower the carbon footprint of port operations and the environmental effect of port activities (Sogut and Erdoğan, 2022). When installing energy-efficient systems and infrastructure, SMSPs usually need more support, such as limited finances and access to technical knowledge. Consequently, SMSPs need

help implementing new technology and best practices that increase their energy efficiency. Small port research is required to discover cost-effective and scalable solutions, to improve energy efficiency, minimize carbon footprints, and encourage sustainable practices.

### **3.2.3. Stakeholder Engagement**

Effective stakeholder involvement is a vital component of sustainable planning, and it is essential for SMSPs, which are usually situated near local communities and companies (Custodio et al., 2022). As small port operations may substantially influence the lives of local communities and the environment, all stakeholders must be included in small port planning and development procedures. More studies are required to understand how to engage and involve stakeholders in small port planning and development processes and guarantee that all stakeholders' needs and concerns are met. This may assist in building confidence and support for long-term planning initiatives and encourage sustainable practices in the port.

### **3.2.4 Best or Most Suitable Practices**

Finally, research on best practices and case studies of sustainable planning in SMSPs is necessary. This data could be used to identify and distribute successful examples of sustainable planning in SMSPs and to provide assistance and lessons learned to other SMSPs striving to implement sustainable planning methods. By exchanging knowledge about best practices and case studies (Fulzele and Shankar, 2022), the port sector could promote sustainable practices, improve capacities, and guarantee that SMSPs are constructed and run appropriately. Addressing these research gaps is crucial to ensure that SMSPs can be constructed and operated sustainably and to encourage sustainable practices in the port sector. New approaches to port planning are being developed as local governments attempt to avoid the patchwork approaches of the past and design plans that facilitate a seamless transition to cleaner and more sustainable forms of transportation. Various plans have been proposed for the transition of ports towards sustainability, such as the Environmental Port Energy Plan (Acciaro et al., 2014), the Green Port Program, plans for environmental protection, climate protection, Climate Initiative, Pollution Prevention and Reduction Plan, Green Port Plan (Lin et al., 2022), and Clean Air Plans (Gibbs et al., 2014), aiming to promote balanced development. Furthermore, energy management is a prominent tool for sustainable port planning, and a large portion of the literature on energy management refers to

environmental management systems (EMS). While the European Seaports Agency (ESPO) encourages European ports to develop environmental management plans, only a portion has implemented EMS. Energy management plans serve as a precursor to port energy certification based on ISO 5001 and EN standards 16001 and the identification of various efficient energy measures and technologies that meet their specific needs.

Several ports have implemented sustainable planning practices and serve as good examples, such as:

- a. Port of Damietta, Egypt: It has implemented a comprehensive sustainability plan that includes renewable energy sources, such as wind and solar power (Balbaa and El-Amary, 2017);
- b. Port of Gijón, Spain: It focuses on economic and social sustainability and has implemented various initiatives to support local businesses and engage the community. For example, the port has developed a business incubation program to support local startups and has established a community engagement program to foster dialogue and collaboration with residents (Castelló-Taliani et al., 2021);
- c. Port of Bar, Montenegro: This port focuses on the development of an inventory of existing equipment that includes detailed data on energy consumption and the compilation of a prioritized list of feasible and promising energy sustainability measures for the port as a whole, but also for specific areas/facilities (e.g., buildings, warehouses, storages, etc.) and operations/equipment (e.g., ship loading/unloading equipment, yard operations equipment, terminal vehicles) (Sdoukopoulos et al., 2019).

### **3.3. Methodology**

Sustainability planning for small and medium ports is a multifaceted endeavor that requires a systematic and tailored approach. This methodology outlines a structured process that empowers port authorities to develop effective sustainability plans that address these ports' unique challenges and opportunities.

The starting point for drawing up a sustainable port development plan (SPDP) should be the decision to improve the current situation and a strong belief that change is needed to enhance sustainability. An SPDP could, therefore, be considered "a strategic plan to address the demands of residents and businesses in the ports and neighboring communities to improve their quality of life". More specifically, an SPDP is a comprehensive and forward-looking strategy designed to guide a port facility's growth, operation, and management in a manner that harmonizes economic, environmental, and social considerations.

This methodology begins with a comprehensive baseline assessment of the port's environmental, social, and economic dimensions. This assessment involves a detailed analysis of energy consumption, GHG emissions, waste management practices, local economic contributions, and community well-being. These quantitative and qualitative data, gathered using questionnaires from stakeholders and relevant reports from the responsible port agencies, provide a clear understanding of the port's current sustainability performance and areas for improvement.

An embedded step in the above-described assessment is identifying the port's critical stakeholders, such as port authorities, local communities, shipping companies, regulatory agencies, and environmental organizations. Valuable insights are gathered through interviews, surveys, and workshops regarding each group's current challenges, opportunities, and sustainability aspirations. This step ensures that the subsequent sustainability plan is well-aligned with the expectations and concerns of the local context.

After recording the key stakeholders' perspectives and priorities, strategies and actions are developed to achieve the established sustainability goals. These strategies include energy efficiency improvements, emission reductions, waste reduction, community engagement initiatives, and economic diversification projects.

The plan is designed for adaptability, recognizing that sustainability planning is an evolving process. Regular monitoring and evaluation mechanisms are embedded within the plan to assess progress, identify deviations, and gather data on the effectiveness of the implemented strategies.

This iterative approach enables port authorities to make informed adjustments, ensuring that the sustainability plan remains responsive to changing circumstances and aligns with the port's and stakeholders' evolving needs. The significant targets of the proposed methodology are illustrated in Table 3.1.

**Table 3.1.** Targets for the proposed planning

<b>Logistics</b>	<b>Mobility</b>	<b>Environment</b>	<b>Economy</b>	<b>People</b>	<b>Governance</b>
Real-time information	Sustainable transport	Pollution reduction	Competitiveness	Social cohesion	Transparency
Smart maintenance	Mobility management	Energy efficiency	Employment	Collaboration	Security
Efficiency and predictability	Smart traffic management	Waste/Water management	Cost reduction	Training and knowledge	E-administration
Automation and robotization		Alternative fuels	Circular economy		

### 3.4 Results

Recently, the approach to port plans has changed academically and professionally. Unlike traditional plan techniques, the proposed SPDP prioritizes citizen participation, stakeholder coordination, policy domains, and collaboration between government entities and corporate players at multiple levels (Schlüter et al., 2020). The most significant distinctions between the traditional plan methodologies and the proposed SPDP are listed below in Figure 3.1:



**Figure 3.1.** Areas of comparison between the traditional and proposed planning

Figure 3.2 details the exact step-by-step implementation and the precise structure of the tasks recommended by word-for-word guidelines. The challenge of implementing an SPDP is adapting it to a given local context, considering each separate port's specific characteristics while maintaining ambitious goals and avoiding inappropriate compromises. The plan presented here is meant to describe these stages in depth. However, because various activities must be conducted in tandem, it can take time to establish which processes and actions should come first during the plan practice stage.



**Figure 3.2.** Phases and steps of the proposed methodology

### **3.4.1. Phase 1: Assessment**

The assessment phase, the first step in the planning process, describes the current situation of the port, including its advantages, disadvantages, opportunities, and threats. Information on energy use, water use, waste production, and emissions is required (Duru et al., 2020). These data identify improvement opportunities and create a long-term plan for the port's future. This phase should involve thorough data collection, analysis, and stakeholder engagement to ensure that all opinions and needs are considered when identifying crucial environmental and social concerns. The data gathered during this phase will be used to develop a sustainable strategy using sustainability concepts such as economic, social, and environmental sustainability. A risk assessment is also necessary to identify potential risks and challenges that could jeopardize the port's sustainability. The Port of Antwerp, Port of Rotterdam, Port of Istanbul, Port of Los Angeles, and Port of Melbourne are just a few of the case studies used by Schippel et al. to apply a port assessment methodology. This research aimed to create and implement comparative methods for evaluating the sustainability of port long-term management plans and port–city development and to confirm the actual impacts in terms of social, economic, and environmental factors. The following is a description of the assessment phase's steps and activities:

#### **3.4.1.1. Identify Environmental and Social Issues**

During the assessment phase, the first step is identifying the environmental and socioeconomic problems that could influence the port's sustainability (Balić et al., 2022). It is crucial to locate possible pollution sources and assess environmental and public health hazards to guarantee that ports run sustainably (Malvestio et al., 2018). Environmental problems typically affecting ports include habitat deterioration and destruction, water pollution from ships and cargo handling activities, and air pollution from trucks, cars, and other vehicles (An et al., 2021; Chang and Tsai, 2021). It is crucial to recognize possible societal problems and provide solutions. Ports frequently face social issues such as noise (Vakili et al., 2020), traffic congestion, and health and safety risks. A thorough literature review and stakeholder consultation should be performed to identify these issues.



#### **3.4.1.2. Data Collection and Analysis**

If ports are to meet future demands, frequent data collection and analysis of port operations, infrastructure, and environmental impacts are required. These data can be gathered using various resources, such as operational reports, infrastructure assessments, and environmental monitoring programs (Zhuang et al., 2022). The kind and amount of information collected will depend on the specific needs of the port, but it should be exhaustive and cover all aspects of operations and impacts (Inkinen et al., 2019). The process of data analysis follows the stage of data collection. To accomplish this, it is necessary to analyze the data to identify trends, patterns, and problem areas. To identify areas for potential improvement, this step aims to better understand the port's operations and effects. Ports can create sustainable plans to help ensure their long-term success by routinely gathering and reviewing information about the port's functions, infrastructure, and environmental impact.

#### **3.4.1.3. Evaluation of the Port's Infrastructure, Operations, and Environmental Impact**

Ports must regularly examine their infrastructure, operations, and environmental effects to guarantee they can meet future needs (Wagner et al., 2022). This includes evaluating the present status of the port's physical infrastructure, such as buildings, docks, and equipment, and identifying areas that require modifications and enhancements. This evaluation should consider aspects such as the age of the infrastructure, its current usage, docks, and potential to meet future needs. Examining the port's operations is the next stage in establishing its long-term sustainability. This entails evaluating the port's present procedures, such as cargo processing, vessel traffic, and maintenance. The port's environmental impact is the final step in determining its sustainability. This includes assessing the port operations' impact on air and water quality, soil and habitats, and wildlife (Kaup et al., 2022). The assessment should identify potential pollution sources, such as ships and cargo handling operations, and assess the risks to human health and the environment. Ports can maintain operational efficiency while protecting the environment and the health and well-being of the local community by regularly assessing these areas and implementing sustainable solutions (Duan et al., 2023).

#### **3.4.1.4. Risk Assessment**

A risk analysis should be conducted as part of the assessment phase to identify potential threats to the port's sustainability (Liu and Yuan, 2023). Risks related to human activities, such as industrial accidents and the release of toxic pollutants, may be included, in addition to risks associated with natural hazards, such as rising sea levels and extreme weather events. Ports can enhance their performance by identifying potential threats and devising plans to lessen or manage them. The risk assessment should be based on a thorough analysis of the available data, and the likelihood and effects of the scenarios should be considered.

#### **3.4.2. Phase 2: Stakeholder Engagement**

Engaging with stakeholders is crucial to ensure that the sustainability plan is comprehensive and satisfies the requirements and expectations of all parties involved. Stakeholders may include port users, local communities, regulatory organizations, and other parties interested in the port's long-term success. Interacting with stakeholders and identifying potential hurdles or issues that need to be addressed can determine the sustainability strategy's potential impact on diverse groups. In general, including stakeholders enhances openness and accountability, fosters trust, improves decision-making, and increases community ownership (Gkargkavouzi et al., 2020). Studying the port of Souda (CHA) in Greece, (Ioannis Argyriou et al., 2022) addressed some of the advantages and disadvantages of stakeholder/citizen involvement in the decision-making process to develop a sustainable port. They examined issues such as citizens' familiarity with sustainable development, how the latter addressed the measures undertaken to develop sustainable ports, anticipated obstacles in carrying them out, and alternatives that could be put forward.

The steps, as well as the activities of the stakeholder engagement phase, are described below:

##### **3.4.2.1. Identify Stakeholders**

The first step in the stakeholder engagement process is identifying and understanding the relevant parties' interests, motivations, and potential concerns (Lam and Li, 2019). Once the stakeholders have been identified, they must be classified according to their level of influence and interest. This will aid in prioritizing which stakeholders to engage with first and determine the most effective engagement methods. This will, in turn, assist in including all relevant stakeholders in the engagement process. All stakeholders must be able to share their perspectives and feedback and

address any concerns. Ports can build positive relationships with stakeholders and ensure they operate sustainably and responsibly by collaborating (Clark Howard, 2018).

#### **3.4.2.2. Establish Communication Channels**

The success of stakeholder engagement depends on effective communication. Setting up transparent and open communication channels, such as public meetings, focus groups, and online forums, will ensure all stakeholders can provide feedback (Santos et al., 2016). By building clear and effective communication channels, ports can ensure that all stakeholders are informed, participate, and have a role in decision-making. By building strong stakeholder relationships, ports can foster community and support for sustainability initiatives.

#### **3.4.2.3. Provide information**

It is crucial to provide information on port planning so that stakeholders can comprehend the present condition and plans of the port and its influence on the surrounding community and the environment for transparency and accountability, to improve decision-making, to build trust, and for better coordination.

#### **3.4.2.4. Address Conflicts**

Conflicts among stakeholders in small port planning can arise due to divergent interests, goals, and priorities (Wamsler, 2017). It is critical to take a collaborative approach that considers the interests and needs of all parties involved. Addressing conflicts constructively and transparently will help build trust and ensure that all stakeholders can be heard and managed effectively through a collaborative, participatory, and transparent approach.

#### **3.4.2.5. Continual Engagement**

This step entails ongoing monitoring, reviewing, and refinement of the plan to align with stakeholders' changing needs and priorities (Bahadorestani et al., 2020). Engagement with stakeholders should be regular throughout a sustainable plan's design and implementation phases rather than a one-time event. Ongoing involvement will help guarantee that the sustainable plan is frequently monitored, reviewed, and adjusted to ensure that it stays relevant and successful despite changing circumstances and that all stakeholders can have input.

### **3.4.3. Phase 3: Goal Setting**

Specific sustainability goals and objectives are identified based on the assessment and stakeholder engagement results. These objectives must be specific, measurable, attainable, relevant, and time-bound. Small port sustainability goals include lowering GHG emissions, increasing energy efficiency, and reducing waste. A well-defined goal-setting process provides a clear direction for the long-term plan, defining the desired outcomes and providing a framework for decision-making activities. (Caliskan, 2022) formulated an all-encompassing framework for implementing sustainability measures in port operations, aiming to facilitate the attainment of sustainable development goal (SDG) targets, specifically for European ports. The objective of their study was to address sustainability concerns about ports within the framework of the SDGs. The steps, as well as the activities of the goal-setting phase, are described as follows:

#### **3.4.3.1. Assess the Current State**

The first step in goal-setting is to assess the SMSPs' current state. This evaluation should consider the port's environmental, social, and economic aspects and the surrounding community (Drake et al., 2021). Both challenges and opportunities mark the current phase of small sustainable port planning, and stakeholders must collaborate to achieve better results for the overall image of the port. By identifying strengths and weaknesses, setting a plan baseline, anticipating future needs, measuring progress, and building trust, stakeholders can make informed decisions that benefit the port and the community (González-Cancelas et al., 2020).

#### **3.4.3.2. Identify Challenges and Opportunities**

The next step is to identify the challenges and opportunities faced by the small port and its surrounding community (Christodoulou and Cullinane, 2019). These issues can be addressed by implementing new technologies, forming partnerships, and focusing on environmental benefits. SMSPs can reap significant benefits by implementing innovative technologies, collaborating with other stakeholders, and demonstrating a commitment to environmental stewardship. Such benefits include lower operating costs, improved energy efficiency, and increased support for local economies. This will aid in identifying the most relevant and practical goals while considering the needs and perspectives of all parties involved.

#### **3.4.3.3. Involve Stakeholders**

A large number of actors are interested in the port sector. As a result, port planning and development are usually performed in an environment where many interacting and sometimes conflicting interests are involved (Kodzi and Saeed, 2021; Zhang and Lam, 2017). This complexity can create challenges in developing a mission statement, formulating the objectives and strategies for a port, and advancing port development projects. Involving stakeholders in the goal-setting process is critical to ensuring the goals are relevant and practical and considering the appropriate parties' needs and perspectives.

#### **3.4.3.4. Establish Clear and Measurable Goals**

Developing sustainable ports requires the establishment of clear and quantifiable goals in port planning (Guo et al., 2023). SMSPs can take concrete steps towards improving their environmental performance and becoming more sustainable by defining the port's purpose, identifying key performance indicators, setting realistic and measurable goals, and monitoring and evaluating progress. This will contribute to the ports' long-term viability and local communities' growth.

#### **3.4.3.5. Prioritize Goals**

Once goals have been set, they must be ranked according to relevance and realizability. Multiple objectives may compete for limited attention and resources, making this process easier. Prioritizing objectives is necessary to ensure that the limited resources available to SMSPs are used as efficiently as feasible. This will help allocate resources to the most essential and realizable objectives. In addition, decision-makers may choose which activities need urgent attention and which can be deferred (Gacutan et al., 2022). This permits the development of a concise action plan and ensures that the most pressing needs are addressed first.

#### **3.4.3.6. Communicate Objectives**

Effective communication of goals and progress is critical for successful sustainable planning. Stakeholders can understand what the port is trying to achieve and why it is essential if the goals and objectives of the port's sustainability plan are communicated. This can increase support for the project and encourage stakeholders to play an active role in helping the port meet its sustainability goals. Transparency and accountability can also be promoted through effective

communication of sustainability goals. Stakeholders can check what the port is doing to improve its environmental performance and hold it accountable for its actions if it provides regular updates on progress towards its sustainability goals. This can contribute to developing trust and confidence in the port and its sustainability plan.

#### **3.4.3.7. Monitor and Evaluate Progress**

Monitoring and assessing progress towards the port's sustainability goals is critical to successful sustainable planning. The port can evaluate whether it is making the necessary progress toward its sustainability goals by regularly monitoring progress and identifying areas for improvement (Pensieri et al., 2021). This enables the port to make informed resource allocation decisions and adjust its sustainability plan. Monitoring and evaluating progress can help build trust and confidence in the port and its sustainability plan and improve its environmental performance. The port can demonstrate its commitment to sustainability and transparency by regularly reporting on progress and making this information publicly available.

#### **3.4.4. Phase 4: Strategy Development**

The strategy development phase of small port sustainability planning is critical for translating the goals and objectives established during the goal-setting phase into concrete, actionable plans (Bešković and Bajec, 2021). The strategies developed during this phase determine how the small port will work towards achieving its long-term goals and must be tailored to the port's and the surrounding community's specific needs and circumstances (Hua et al., 2020). In addition, it provides a road map for accomplishing the long-term objectives defined during the goal-setting phase by detailing the particular activities to be undertaken and the required resources. The steps, as well as the actions of the strategy development phase, are described as follows:

##### **3.4.4.1. Examine Goals and Objectives**

Examining goals and objectives is crucial to port planning because it forms the basis for the entire planning procedure. By clearly outlining the port's aims and objectives, decision-makers can guarantee that all efforts and resources are focused on attaining these objectives. This allows all stakeholders, including port authorities, shipping corporations, and government agencies, to develop a shared vision and a feeling of purpose (Parola et al., 2018). Examining goals and

objectives helps prioritize the port's growth (Sunitiyoso et al., 2022). By understanding what is most essential to the port and its stakeholders, decision-makers can allocate resources and prioritize initiatives with the highest likelihood of achieving these objectives. This may result in more efficient use of resources, less risk, and enhanced results.

#### **3.4.4.2. Conduct a Gap Analysis**

A gap analysis determines the difference between the small port's current state and the desired outcomes established during the goal-setting phase. This analysis provides valuable insights into a port's strengths and weaknesses and helps determine the required improvements to achieve the desired state. Port planners can ensure that the port is well-positioned to meet future demands and deliver the best possible outcomes for all stakeholders by conducting a thorough gap analysis. A performance gap analysis may also assist in identifying possibilities for innovation and expansion. By analyzing the port's strengths and limitations, decision-makers may find areas where new technology or novel techniques can enhance performance and boost competitiveness (Park et al., 2021). This may help the port remain ahead of the curve and serve its customers and stakeholders more effectively.

#### **3.4.4.3. Involve Stakeholders**

It is critical to include stakeholders in the strategy development process to ensure that the strategies developed are practical and relevant, considering the needs and perspectives of all appropriate parties (Svanberg et al., 2021).

#### **3.4.4.4. Identify and Prioritize Strategies**

Various options for developing and improving the port are evaluated and prioritized during this phase based on feasibility, impact, and cost-effectiveness factors (Pamucar et al., 2022). This step aims to identify the most viable and effective strategies for moving the port forward and ensuring its long-term success. Effective planning is critical here for the overall success of the port planning process. By analyzing various potential strategies and choosing the most effective and efficient alternatives, decision-makers may concentrate their resources on the plans with the most significant impact.

#### **3.4.4.5. Develop Implementation Plans**

Following the identification and prioritization of strategies, implementation plans must be developed, outlining the specific actions to be taken, the resources required, and the timeline for implementation (Mthembu and Chasomeris, 2022). The implementation plan must be comprehensive while remaining flexible to accommodate unexpected obstacles. This phase ensures that all stakeholders understand the project objectives, scope, timeline, and each team member's roles and responsibilities. The project team can ensure that the proposed port project is completed on time, within budget, and to the desired quality standards by effectively planning and executing the implementation process.

#### **3.4.4.6. Communicate Strategies**

Effective communication strategies are required for small port planning to successfully implement plans and projects (Teixeira and Canciglieri Junior, 2019). Regular meetings with stakeholders, clear and transparent communication about goals and progress, and the use of visual aids, such as presentations and models, to convey information effectively are examples of these strategies. It is critical to actively seek stakeholder feedback and be open to incorporating their ideas and concerns into the planning process. Building trust and keeping lines of communication open can help small port planning initiatives succeed.

#### **3.4.4.7. Monitor and Evaluate Progress**

Ongoing monitoring and evaluation progress are critical to the success of the long-term plan. Monitoring and evaluating progress may assist in discovering areas for improvement and improving the overall quality of the port planning process. By regularly analyzing the port's performance, decision-makers may identify areas where procedures or systems need to be enhanced to boost efficiency and performance. This may improve the overall quality of the port planning process and guarantee that the port operates at its maximum capacity.



### **3.4.5. Phase 5: Implementation**

This is the stage at which the strategies and action plans developed during the strategy development phase are implemented. The port's and the surrounding community's long-term goals and objectives established during the goal-setting phase are translated into tangible outcomes. The implementation phase increases accountability by ensuring that the strategies and action plans are implemented and the results are tracked and measured. The steps, as well as the activities of the strategy development phase, are described as follows:

#### **3.4.5.1. Allocate Resources**

Allocating resources is an essential step in planning for SMSPs seeking sustainability. It entails determining the resources required to implement a sustainable plan and how they will be distributed (Kim et al., 2022). This includes allocating financial, human, and material resources effectively and efficiently to ensure the plan's successful implementation. The resource allocation phase aims to provide the right resources available at the right time, place, and quantities to support the SMSPs' long-term development.

#### **3.4.5.2. Establish a Project Team**

A project team is vital to achieving success since this requires organizing and directing the work of a group of individuals to accomplish a common objective. Creating a project team entails identifying the right people, defining their roles and responsibilities, and establishing precise performance and communication expectations (JØrgensen, 2018). A well-organized project team can boost efficiency, productivity, and collaboration, thus resulting in better outcomes and project success (Varajão et al., 2022).

#### **3.4.5.3. Develop an Implementation Schedule**

The implementation timeline is a crucial aspect of every project and acts as a road map for success. It is essential to have a clear and accurate plan in place for port planning to guarantee that all activities run smoothly and efficiently (Pagano et al., 2022). The timetable must account for all facets of port operations, including people, equipment, resource deployment, maintenance, and repair tasks. By designing a clear and well-structured implementation schedule, we can meet project deadlines and ensure the timely accomplishment of all activities.

#### **3.4.5.4. Communicate the Plan**

Communication of the plan is an integral aspect of port planning, as it ensures that all stakeholders are aware of the port's goals and objectives and comprehend their role in supporting the plan. Effective communication can foster a feeling of ownership and responsibility among all stakeholders and guarantee that everyone is working towards the shared goal of a prosperous and sustainable port. By clearly and effectively communicating the plan, decision-makers can ensure that all stakeholders understand the port's priorities and objectives and know the activities needed to accomplish these objectives.

#### **3.5.5. Monitor Progress**

Monitoring progress is an ongoing process that allows for adjustments and ensures the sustainable plan remains relevant and practical (see par. 4.7).

#### **3.5.6. Evaluate Outcomes**

Evaluating port planning outcomes is essential for ensuring the effectiveness and efficiency of a port's operations. It entails evaluating the results of previous planning decisions and determining whether the desired goals and objectives have been met. This evaluation process identifies areas for improvement and directs future planning efforts in response to changing demands and challenges. It is a systematic approach to determining the impact of planning decisions on port performance and the return on investment for stakeholders.

### **3.6. Phase 6: Monitoring and Evaluation**

The monitoring and evaluation phase of SMSPs is the stage in which the progress of the sustainable plan is monitored and evaluated to ensure that the desired outcomes have been achieved and that the plan remains relevant and practical (QUYEN et al., 2018). The steps, as well as the activities of the strategy development phase, are described as follows:

#### **3.6.1. Establish Monitoring and Evaluation (M&E) Indicators**

Establishing effective M&E indicators during project planning is critical to ensuring success and sustainability (He et al., 2021). M&E indicators are used to track progress, assess impacts, and identify areas for improvement (Bentaleb et al., 2015). A well-designed M&E system provides

project managers with valuable feedback, allowing them to make well-informed decisions, adjust strategies, and allocate resources accordingly. When developing M&E indicators, it is essential to consider the project's goals and objectives, target population, and desired outcomes. A clear and concise M&E plan ensures project success and demonstrates accountability and transparency to stakeholders.

### **3.6.2. Develop a Monitoring and Evaluation Plan**

An M&E plan is essential for a project's success and sustainability. A well-designed M&E plan can provide valuable insights into project progress and impacts, enabling project managers to make well-informed decisions, adjust strategies, and effectively allocate resources. Furthermore, it includes data collection and analysis frequency functions to ensure the project stays on track and progresses toward its goals and objectives.

### **3.6.3. Conduct Regular Monitoring**

Regular monitoring is a crucial aspect of port planning since it ensures that the plan is successfully implemented and that progress is made toward the desired outcomes. Regular monitoring enables decision-makers to evaluate the efficacy of their tactics and discover improvement opportunities, which may be vital to accomplishing the port's goals and objectives. Through frequent monitoring, decision-makers can evaluate the port's performance and identify potential concerns or obstacles. These data may then be utilized to make educated judgments and execute any required improvements to enhance the port's overall performance. Regular monitoring can guarantee that the port is running at its maximum capacity and that all stakeholders cooperate to achieve the shared objective of a successful and sustainable port.

### **3.6.4. Evaluate Outcomes**

Evaluation of outcomes is an essential component of port planning, as it enables decision-makers to analyze the efficacy of their methods and quantify the port-wide impact of their efforts. By analyzing results, decision-makers can identify areas for improvement and make well-informed choices to guarantee that the port runs at its maximum capacity and that all stakeholders work towards the shared goal of a successful and sustainable port. By regularly evaluating results, decision-makers can review the port's performance and decide whether their initiatives have

produced the intended results. These data may then be utilized to make the appropriate modifications to enhance the port's overall performance. By reviewing results, decision-makers can verify that their strategies are aligned with the port's aims and objectives and that they are advancing towards a prosperous and sustainable future.

#### **3.6.5. Communicate Progress**

Progress reporting is essential to port planning, as it keeps stakeholders informed and involved in the planning process. By discussing progress regularly, decision-makers can show their commitment to openness and accountability and develop stakeholder confidence (Housni et al., 2022). This may ensure that the port has the support of the local community and the industry and that all stakeholders strive toward the common goal of a prosperous and sustainable port. Moreover, effective communication of progress may build a feeling of ownership and responsibility among all parties involved. By routinely reporting on the port's development, decision-makers can encourage stakeholders to take an active interest in the planning process and feel responsible for the port's future. This ensures all stakeholders align with the port's aims and objectives and work together towards a prosperous and sustainable future.

#### **3.6.6. Make Adjustments**

During this phase, changes and improvements to previously developed plans are made based on new information, stakeholder feedback, and emerging requirements. The goal is to ensure that the port development project corresponds with the evolving needs of stakeholders, adheres to the project's budget, and achieves the technical and operational standards set out. To make well-informed decisions and create a comprehensive, flexible, and practical plan, the project team, stakeholders, and relevant authorities must collaborate during this phase.

### **3.7. Phase 7: Continuous Improvement**

This is the final step in the process of long-term planning. It is the stage at which the lessons learned from the monitoring and evaluation phase are applied to improve the long-term plan and ensure that it remains relevant and practical. This contributes to progress toward the goals and objectives established during the goal-setting phase, providing the desired outcomes are realized. The continuous improvement phase is an ongoing process, and the sustainable planning process

should be repeated regularly to keep the sustainable plan relevant and practical and progress toward the goals and objectives on track (Butler et al., 2018). The steps, as well as the activities of the strategy development phase, are described as follows:

### **3.7.1. Lessons Learned**

The lessons learned are a record of a project or initiative that highlights what worked well and what did not, and this is a necessary tool for effective port planning. Lessons learned throughout the port development process are crucial because they give significant insight into what went well and what could be improved. By reflecting on the lessons gained, decision-makers may identify best practices and make educated choices to safeguard the port's future viability. Learning from previous experiences is vital for the port planning process's constant development and innovation. By reflecting on the lessons learned, decision-makers can identify areas for improvement and modify the planning process as appropriate. This guarantees, in turn, that the port runs at its maximum capacity and that all stakeholders collaborate for a prosperous and sustainable future.

### **3.7.2. Identify New Challenges for the Next Plan**

New difficulties arise daily in port planning, which is continuously evolving. In the upcoming years, port planners will encounter unique and distinctive challenges that will test their capacity to oversee and improve current port operations. Port planning is a dynamic and challenging area that demands adjusting to new and changing situations. As they try to make ports more sustainable, efficient, and safe and handle the growing complexity of global commerce, port planners will encounter specific challenges in future years. These problems will require innovative solutions and a solid knowledge of the sector's recent trends and technology.

### **3.7.3. Update Port Planning Regularly**

Port planning is a vital aspect of the shipping industry, and port planners must frequently analyze and change their plans to meet the industry's needs. Regularly updating the port planning procedure is necessary for several reasons (Zhang et al., 2017). First, the port industry is ever-evolving and changing, requiring periodic revisions to the port planning procedure. Second, revising the port planning process regularly ensures that the port runs at its maximum capacity and that all stakeholders work towards the shared objective of a successful and sustainable port. Third,

periodically reviewing the port planning process can assist in identifying areas for improvement and making any required improvements. Lastly, updating the port planning process can assist in maintaining momentum and keep stakeholders motivated and involved in the planning process.

### **3.8 Conclusions**

SMSPs are critical to coastal community development and marine environment preservation. Implementing sustainable planning strategies in SMSPs can ensure responsible resource use, promote economic growth, and improve residents' quality of life. This can be accomplished by combining various approaches, such as environmentally friendly infrastructure development, renewable energy adoption, and effective waste management practices. For instance, investing in environmentally friendly infrastructure and renewable energy might generate new employment prospects in industries such as developing renewable energy and sustainable tourism. SMSPs can strike a balance that benefits everyone by considering sustainable planning initiatives' environmental and economic impact. Moreover, effective collaboration among stakeholders, including government agencies, local communities, and private firms, is essential for the success of SMSP efforts. By addressing sustainability, SMSPs can ensure a bright and prosperous future for future generations.

The numerous case studies discussed in papers show how specific strategies and solutions to promote sustainability can produce unsustainable outcomes if their effects on various sectors or scales are not anticipated and adequately addressed. This survey's contribution is to provide a comprehensive understanding of the current state of research in the field, as well as valuable insights into best practices and methodologies, and to serve as a helpful resource for researchers, policymakers, and practitioners. This promotes the development of more sustainable ports and ensures that the port sector is better equipped to meet future challenges by contributing to a better understanding of sustainable port planning.

More analytically, this guide provides a thorough framework that identifies the critical elements affecting the sustainability of SMSPs and discusses the activities stakeholders may undertake to improve sustainability. It highlights the necessity for collaboration between port authorities, port users, and local communities to ensure that the sustainability plan reflects the interests and concerns of all stakeholders. Environmental sustainability is emphasized heavily in this particular guide for SMSP sustainability planning, which is another crucial feature. Furthermore, it describes

how SMSPs can reduce environmental effects by lowering emissions and managing waste. In addition, it emphasizes the significance of economic sustainability, as SMSPs are frequently located in economically weak areas, and their economic viability is crucial to the local economy (Vukić and Kraemer, 2021).

It is a valuable resource for researchers looking to advance the field of sustainable port planning. By comprehensively assessing the available literature on the issue, this survey intends to aid academics in identifying potential research gaps and directing their attention to areas that require additional examination. This can also contribute to well-informed and relevant future research on sustainable port planning, which is critical for advancing the field and improving the port sector's sustainability.

Future work on SMSPs should center on initiatives that promote clean energy, waste management, water management, sustainable transportation, ecosystem protection, community building, sustainable tourism, alternative transportation infrastructure, sustainable development, and stakeholder engagement. SMSPs can build sustainable and resilient communities that support local economies and protect the environment for future generations by prioritizing these initiatives and collaborating closely with stakeholders. However, each port and community's unique circumstances and needs will determine the specific focus and priorities. They can play an essential role in creating a more sustainable and resilient future for their communities by taking a proactive approach to sustainable planning and development.

## **Chapter 4- From theoretical to practical part of PhD Thesis**



#### **4.1 Theoretical part**

The theoretical foundation of the PhD Thesis on small/medium port sustainability planning establishes a framework that recognizes the unique challenges and opportunities inherent in smaller port environments. Drawing from various disciplines such as environmental science, economics, and planning, the theoretical aspect delves into the intricacies of sustainability within the context of smaller ports. It addresses resource constraints, community engagement, and the interplay between economic viability and ecological stewardship. This theoretical groundwork ensures that the subsequent practical phase is not a generic application of sustainability principles but a tailored approach that considers the specific characteristics of SMSPs.

The theoretical framework of the PhD Thesis on port sustainability planning also addresses the dynamic nature of environmental and economic conditions. It anticipates and adapts to emerging challenges such as climate change, technological advancements, and shifts in global trade patterns. The research aims to equip port authorities and stakeholders with tools to navigate uncertainties and proactively respond to evolving sustainability requirements by exploring theoretical concepts that embrace flexibility and resilience. Therefore, the theoretical underpinnings guide developing adaptable strategies that meet current standards and anticipate and prepare for future challenges.

#### **4.2 Practical part**

As the research transitions from theory to practice, it meticulously examines real-world cases, collaborating closely with stakeholders such as port authorities, local communities, and industry players. SMSPs often operate within tight budgets and face distinctive socio-economic challenges. The practical component of the Thesis thus seeks to identify pragmatic solutions that align with the theoretical concepts established earlier. By considering the financial limitations and community dynamics specific to smaller ports, the research aims to develop sustainable strategies that are theoretically sound but also practical and feasible in the unique context of smaller port operations.

Furthermore, the practical implementation phase explores the role of local governance structures and community involvement in small/medium port sustainability. The theoretical understanding of inclusive governance is translated into actionable initiatives that empower local communities and integrate their perspectives into decision-making processes. This approach recognizes that smaller ports are often deeply embedded in regional economies, and their sustainability is

intertwined with the well-being of adjacent communities. The Thesis thus seeks to bridge the theoretical concept with practical models that foster collaboration, transparency, and shared responsibility, enhancing the overall sustainability of SMSPs.

In addition to addressing economic and community dynamics, the research explores innovative technologies and practices tailored to smaller ports' scale and resources. This may involve the development of cost-effective digital infrastructure, the integration of sensor technologies for environmental monitoring, or the implementation of lean and efficient logistics systems. The practical adaptation of theoretical advancements ensures that smaller ports can leverage contemporary tools to enhance their sustainability without overwhelming financial burdens.

In conclusion, integrating theory and practice in this PhD Thesis on small/medium port sustainability planning is a nuanced and context-specific endeavor. It not only adapts theoretical frameworks to the distinctive characteristics of smaller ports but also contributes practical insights that enrich and refine these theoretical constructs. This holistic approach seeks to provide a comprehensive and tailored understanding of sustainability planning for small and medium-sized ports, fostering the development of effective and contextually relevant strategies for their long-term viability and resilience.

#### **4.3 Flow of PhD Thesis**

In recent years, the sustainable planning of SMSPs has emerged as a critical concern for coastal communities and maritime industries. To address the complexities of this planning process, this PhD Thesis proposes a comprehensive flow. The chart flow (Figure 4.1) describes the steps we followed for port development that consider environmental, economic, and social sustainability. The first phase involves the determination of the research framework. In this step, the research framework was determined as a critical step in developing a PhD Thesis. The foundation of this doctoral Thesis lies in the meticulous process of formulating precise and concise research objectives and aims. These pivotal elements serve as guiding beacons, directing the trajectory of the investigation while delineating its purpose and scope. They provide a clear direction and purpose for the study, guiding systematic and rigorous inquiry. They serve as a roadmap, outlining the scope and boundaries of the research, and often act as criteria against which the success or completion of the study can be evaluated. These objectives structure the research

process and ensure the coherence and relevance of the findings to the research questions, contributing to the overall significance of the PhD Thesis.

The second phase, focused on finding and analyzing literature for a PhD Thesis, is a pivotal step that contributes significantly to shaping the research direction. It involves a review and synthesis of existing scholarly works, encompassing articles, books, theses, and other relevant publications within the field of study. This comprehensive examination allowed us to identify the current knowledge, critical theories, methodologies, and findings related to their research topic. As we navigated through the literature, we aimed to pinpoint gaps, contradictions, or unresolved issues in existing research. This critical analysis forms the basis for formulating research goals and questions. By identifying these gaps, we can articulate specific research objectives and craft-focused research questions that address these lacunae. These gaps act as guiding beacons, directing the trajectory of the study and paving the way for a systematic and purposeful exploration of the chosen research area.

Furthermore, determining research goals and questions is a strategic process that requires careful consideration of the broader objectives and significance of the study. These goals/questions served as the foundation upon which the entire research methodology will be built. They guide the selection of appropriate research methods, data collection techniques, and analysis tools, ensuring that the study remains focused and aims to address the identified gaps comprehensively.

The third step, focused on determining the research methods and tools, is a critical phase in developing a PhD Thesis, as it involves selecting the most appropriate approaches to address the research objectives and questions. The chosen methods should align with the theoretical framework and contribute to the depth of inquiry required for the Thesis. These tools encompass surveys, interviews, observations, statistical software, or other specialized techniques tailored to the research methodology. The selection of these methods and tools is crucial in ensuring the study's reliability, validity, and rigor while enabling researchers to systematically gather and analyze data to address their research questions.

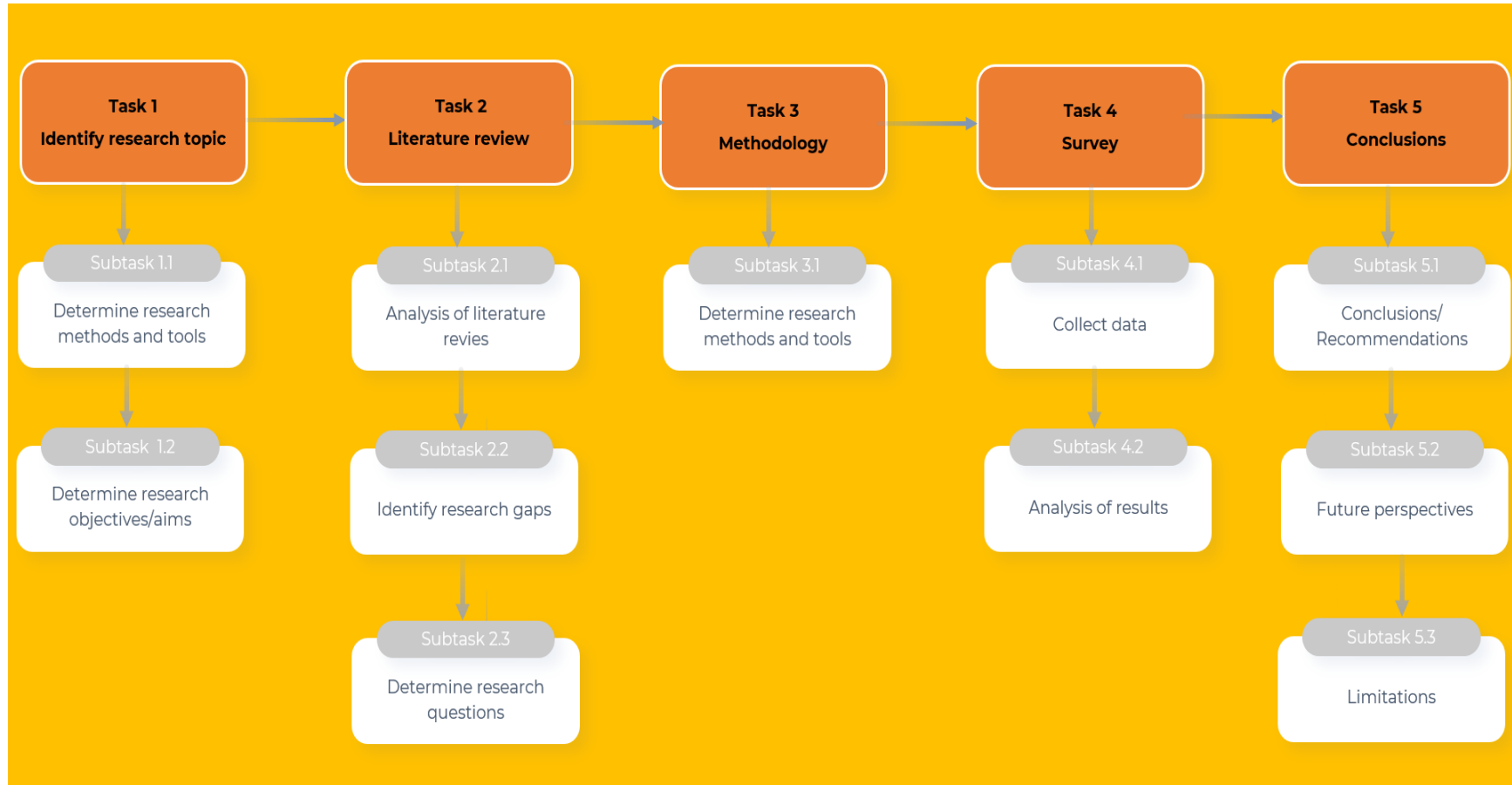
The fourth step centers on the core of this doctoral Thesis and involves the meticulous collection of data and the rigorous analysis of results, constituting the essence of empirical inquiry.

This process encompasses various methodologies, including qualitative, quantitative, or mixed-method paradigms, each selected judiciously to capture the nuances of the research phenomenon. Subsequently, the amassed data undergoes a systematic and comprehensive analysis, employing

established and innovative analytical tools and techniques. This analytical phase is a meticulous undertaking, aiming to decipher patterns and correlations within the data and to draw insightful conclusions, test hypotheses, and derive meaningful interpretations. The synThesis of these analyses forms the bedrock upon which the findings, implications, and contributions of this research endeavor.

The culmination of this doctoral Thesis converges in its conclusions, recommendations, future perspectives, and acknowledgment of limitations. Drawing from the analysis, the conclusions synthesize the key findings, illuminating the answers to the research questions and addressing the objectives set forth at the outset. Moreover, recommendations are offered, grounded in the empirical evidence, to guide practitioners, policymakers, or stakeholders in applying the research outcomes in practical settings or further investigations. Looking ahead, the Thesis presents a vista of future perspectives, highlighting potential avenues for subsequent research, innovative methodologies, or unexplored dimensions that could fortify and expand upon the current study. However, the Thesis also acknowledges its limitations, delineating the research's boundaries and elucidating constraints such as sample size, methodology limitations, or external factors that may have influenced the findings. Embracing these limitations is a pathway informing the evolution of subsequent scholarly endeavors in the field.

**Figure 4.1.** Steps of PhD Thesis



## **4.4 Case studies**

In transitioning from the theoretical exploration of sustainable port design in the doctoral Thesis to its practical implementation, a comprehensive investigation was conducted across specific study areas. These focus areas encompassed the ports of Souda, Rethymnon, Heraklion, and Sitia, located in Crete, Greece.

### **4.4.1 Crete**

Crete, the largest of the Greek islands, is vital in maritime trade in the Eastern Mediterranean. Its geographical location, ports, and historical significance have made it a crucial hub for commercial shipping and trade. Here are several critical reasons for the importance of Crete in maritime trade:

#### **a. Strategic Location**

Crete is strategically situated at the crossroads of major maritime routes in the Eastern Mediterranean. Its location between Europe and Africa places it at the center of trade between these continents. Ships passing through the Mediterranean often navigate close to Crete, making it an essential waypoint for vessels moving goods between regions.

#### **b. Well-established Ports**

Crete boasts several well-developed and strategic ports, including Heraklion and Chania. These ports have modern infrastructure and facilities and can handle a wide range of cargo, including containers, bulk goods, and liquid cargo. The efficiency of these ports contributes significantly to the island's role in facilitating maritime trade.

#### **c. Connectivity**

The island's ports are well-connected to other major ports in the Mediterranean and beyond. This connectivity ensures that Crete serves as a central transshipment point for cargo moving between these regions, increasing the efficiency of global supply chains.

#### **d. Tourism**

Crete's appeal as a tourist destination also plays a significant role in maritime trade. The island's beautiful beaches, historic sites, and vibrant culture draw millions of tourists annually. This tourism boosts demand for imported goods and fuels the local economy, relying heavily on maritime trade to supply food, goods, and materials to support the tourism industry.

**e. Energy Resources**

Crete is also noteworthy for its emerging role in the energy sector. The island is a potential hub for renewable energy like wind and solar power. The island's geographical position makes it attractive for undersea cable connections that can transmit energy, further increasing its importance in the maritime energy trade.

**f. Historical Significance**

The historical significance of Crete in maritime trade must be considered. The island's role as a center of trade and cultural exchange dates back to ancient times, including its importance in the Minoan civilization, one of the earliest trading powers in the Mediterranean. This historical legacy has left an enduring mark on Crete's identity as a maritime trading center.

Below it is a more analytical description of each port:

**Port of Souda (CHA)**

The CHA is located on the northwest coast of the Greek island of Crete. It is considered one of the largest and safest ports in the eastern Mediterranean. It is a major commercial and military port for Greece and the European Union, making it an important international trade and commerce transportation hub. It has modern facilities and infrastructure to accommodate large cargo ships, tankers, passenger vessels, military ships, and submarines. In addition to its commercial and transportation activities, the CHA is a substantial military base for Greece and the NATO alliance. The port's strategic location at the crossroads of the Mediterranean and the Aegean makes it an ideal base for naval operations, and it has played a critical role in supporting NATO missions in the region. Despite its importance as a commercial and military port, the CHA remains a beautiful and welcoming destination for tourists and travelers. Its stunning natural scenery, crystal-clear waters, and rich history make it a fascinating and unique holiday place. In conclusion, the CHA is a vital economic and strategic asset for Greece and the European Union and a popular tourist destination.

**Port of Heraklion (HER)**

The HER is located on the northern coast of the island of Crete in Greece. It is the largest port in Crete and one of the busiest ports in Greece, serving as a significant hub for ferry connections between Crete and other Greek islands and mainland Greece. Some of the main destinations served by the HER include Piraeus (the port of Athens), Santorini, Mykonos, Rhodes, and other nearby islands. The HER has a long history, dating back to ancient times, and has played an essential role

in the island's economic and cultural development. Today, it is a modern, well-equipped port that handles passenger and cargo traffic with advanced technology and infrastructure to handle large volumes of cargo and passenger traffic. It has several quays and berths that can accommodate various types of vessels, including ferries, cruise ships, and cargo carriers.

The HER plays a crucial role in the economy of Crete, as it provides a vital link between the island and the mainland of Greece and other parts of the world. It handles a significant portion of the island's imports and exports, including agricultural products, manufactured goods, and tourism-related services. In addition to its economic significance, the HER is also a cultural and historical landmark, reflecting the rich heritage of Crete and the Mediterranean. Moreover, the HER is a hub of transportation, commerce, tourism, and cultural exchange. Thousands of visitors pass through the port every year, arriving by ferry or cruise ship to explore the island of Crete and its many attractions.

The port offers various services and amenities to accommodate the needs of tourists, including transportation, accommodation, and tour packages. Numerous tour operators offer guided tours of the city and its surrounding areas and excursions to other parts of Crete. In addition to its role in tourism, the HER is also a cultural exchange center, as it welcomes visitors from all over the world and facilitates the exchange of ideas, traditions, and values.

### **Port of Rethymno (RET)**

The RET is a small port located on the northern coast of the island of Crete in Greece. It is situated in the city of Rethymno, the third-largest city on the island. The RET is primarily used for commercial and fishing purposes. It is not a major hub for passenger traffic, although some ferry services operate from the port to other destinations in Greece. It plays a significant role in the region's economic development, particularly in commercial and fishing operations. Although the RET primarily focuses on commercial and fishing operations, it also has some passenger services. During the summer, ferry services operate from the port to other destinations in Greece, including Athens, Santorini, and Mykonos. The port has a small passenger terminal with waiting areas, ticketing offices, and other amenities for travelers. The RET plays a vital role in the region's economy. Its commercial and fishing operations are essential for transporting goods, while its passenger services provide connectivity to other destinations in Greece. In addition to its primary operations, the RET also significantly impacts the local community and the environment. Overall,



the RET is an essential hub for transporting goods and passengers in the region. Its operations significantly impact the local economy, employment, and environment.

### **Port of Sitia (SIT)**

The SIT is a small harbor located on the northeastern coast of the island of Crete, Greece. It serves as a transportation hub for passenger ferries and small fishing boats. The port is located in Sitia, the easternmost city on Crete. The port offers connections to other Greek islands, such as Rhodes, Karpathos, and Kasos, as well as to the mainland port of Piraeus near Athens. There are also local ferry services to nearby towns and beaches. In addition to its ferry services, the port is also home to a small marina where visitors can dock their private boats. The marina offers facilities such as electricity, water, and fuel, as well as a repair shop for minor repairs. The port is home to a small fishing fleet, which operates primarily in the waters surrounding the town. While the port primarily focuses on passenger transport, it also handles some cargo shipments. These shipments typically consist of small quantities of goods, such as food and supplies for local businesses. Overall, the SIT plays a vital role in the transportation and economic activities of the town and surrounding area. Its ferry services connect the city with other destinations, while its marina and fishing activities provide significant recreational and commercial opportunities.

The purpose of this practical phase was to bridge the gap between academic concepts and real-world applications, shedding light on the tangible implications of sustainable port planning. The study delved into infrastructure assessment, environmental impact analysis, community integration, safety measures, and economic viability. The research aimed to provide actionable insights for advancing sustainable practices within these port regions by examining these critical dimensions.

Furthermore, the practical segment emphasized a collaborative approach, engaging local communities, businesses, and relevant authorities. The goal was to develop tailored solutions that promote the ports' ecological resilience and align with stakeholders' diverse needs and aspirations. By navigating from theory to practice in these specific study areas, the research seeks to contribute valuable knowledge and guidelines for effectively designing and managing sustainable ports in the broader context of maritime infrastructure.

## **Chapter 5- Ranking measures to improve the sustainability of Mediterranean ports based on multicriteria decision analysis.**

## 5.1 Introduction

Although port activities contribute significantly to most countries' economic development, it is also recognized that their actions might adversely affect natural resources (Woo et al., 2018). Optimizing port operations aims at lower energy consumption, better waste management, and reduced gas emissions across the whole range of port activities (Woo et al., 2018). This new reality is unstable and continually evolves in an economic environment of intense global competition and technological growth (Tae YEO et al., 2015). Promoting the ports' services and improving operations significantly attract more end-users (vessels, passengers) (Bjerkan and Seter, 2019). The additional services must be enhanced non-stop through marketing strategies and planning. This way, the authorities achieve their short-term goals and increase the port's competitiveness. Port decision-makers need to analyze their market, set their goals, formulate their strategy, and identify their goals (Bjerkan and Seter, 2019).

In this context, it is essential to incorporate social acceptance to implement new measures (Jansen et al., 2018). The attitude of society towards any change should be investigated as a priority. Although everyone may acknowledge the imperative need for emissions reduction, it is not equally easy or self-evident for all to consent to construct facilities that promote green energy, e.g., wind farms, for several environmental, aesthetic, and financial reasons. The residents' arguments can be attributed to various reasons, including loss of land use and environmental degradation (Hidalgo-Gallego and Núñez-Sánchez, 2023).

Green ports answer these challenges (Sifakis and Tsoutsos, 2020). The term "Green Port" or "Sustainable Port" is used for a port that aims at sustainable development, combining the management of environmental problems with social and economic growth (Lam and Li, 2019). The complexity of energy and environmental systems, coupled with the severity of the effects of human actions on the planet, renders decision-making procedures from different stakeholders imperative (Delmas and Toffel, 2004). Conflicts between stakeholders usually stem from the enforcement of environmental protection policies application and the restrictions placed on exploiting natural resources. Stakeholders have different or contrasting interests, so port management is a complex process that requires proper planning. A stakeholder management approach should balance economic, social, and environmental aspects (Delmas and Toffel, 2004). The global trend is to design and implement appropriate environmental management plans for each port. To support these policies, the EU Policy for the Protection of the Marine and Ports

Environment includes scientific research and implementation, technology and education, control mechanisms, and responsibilities of the polluter. They are all expressed through a complex institutional framework, including a series of Community Law Acts and Directives with great diversity (Qiu and Jones, 2013).

With the most extensive coastline across the EU, Greece has an expanded port network due to its peculiarity and numerous dispersed islands. Greek ports are a significant factor in the country's economic development, both as a hub of international and national trade and as a tourist destination (Zlatoudis, 2017). The contribution of maritime transport and ports, particularly to the Greek economy, is significant. In the Greek environmental and energy policy context, promoting environmental protection, rational use, and managing natural resources and RES is a prerequisite for ensuring a sound development plan.

The main objective of this research is to examine the stakeholders' degree of responsiveness /acceptance of the proposed sustainable development measures. Therefore, the scientific question of this survey was «What is the degree of acceptance of stakeholders in the application of new technologies (smart networks, cold ironing) that are conducive to green development?».

In this context, the research relied on measures that satisfy environmental, social, technological, and economic criteria. The responsible bodies seek to optimize all ports' operational needs while considering environmental protection without affecting commercial activities (Gogas et al., 2014).

This research develops a theoretical model to find appropriate technological and non-technological tools based on which the involved parties meet their port sustainability needs. More specifically, this research contributes to the existing knowledge by extending the previous literature on sustainable development in two main areas:

First, although stakeholders' involvement in sustainability management is widely recognized and studied in past works for most large ports, no thorough research has been done on medium and smaller ports. Current findings from studies of large ports are not applicable due to significant differences in how these ports respond to social, political, and economic pressures (Duru et al., 2020). Small ports usually lack the necessary financial resources to achieve sustainability (Bjerkkan and Seter, 2019), often because research is needed to study the stakeholders' attitudes toward improving sustainable infrastructure indicators.

Secondly, this research intends to link the involved parties' preferences with the application of innovative technological tools, such as smart grids, cold ironing, etc. What is sought after through innovation is the determination of the degree to which stakeholders are willing to incorporate new technologies that will be used as tools for optimizing port sustainability.

The research is original because there have been few relevant previous attempts to study the stakeholders' views on implementing various innovative solutions using multi-criteria analysis. Moreover, the research focuses on small-medium island ports, which is an additional element of originality.

The literature review has also revealed a gap regarding the social acceptance of sustainable measures for small SMSPs. Even though many studies focus on the effectiveness of various port measures, it has yet to be adequately investigated whether the stakeholders could accept such measures positively.

With the primary goal of minimizing the environmental impact and achieving social cohesion and development, the research methodology can be an example to follow by other ports. The results could be critical in shaping stakeholders' decision-making strategy. Also, the findings become valuable tools, as they highlight issues such as new forms of energy and intelligent systems that can form the basis for related research.

The findings of the proposed research might prove helpful, in addition to policymakers, to citizens and professionals in the wider region.

This study's added value to the existing knowledge lies in selecting the optimal solution for port sustainability, combining the implementation costs and the time required.

## **5.2 Literature review**

Extensive research in port sustainability literature has shown that creating sustainable ports is a critical issue of our time. Consolidating economic growth, protecting the environment, and creating new jobs are significant challenges for port sustainability and depend on innovative solutions. In the existing published studies, several measures have already been implemented in various ports, and their impacts have been estimated. However, there needs to be more investigation into the social acceptance factor in implementing these measures. The research complements the existing literature by making suggestions to reduce the conflicting interests among those involved in the port and to maximize their potential benefit.

In addition, many studies have been published on port sustainability assessment. However, only a few specialize in small ports. Due to the rapid growth in maritime transportation, the need for research in this field is more significant than ever since smaller ports can also contribute significantly and play a vital role.

The limited, applicable published research work does not allow for safe conclusions to be drawn on the port authorities' actual cooperation, their perception of sustainability, and the acceptance of techniques and measures available. Specifically, the available studies are mainly about large ports, generating several concerns about the sustainability viewpoints of the smaller ports' stakeholders (Sifakis and Tsoutsos, 2020). Thus, this research aims to consider stakeholders' views on the objectives of requirements and actions. In particular, the study seeks to understand stakeholders' views on the priorities of criteria and actions. This is achieved by exploring their attitudes, thereby contributing to gapping the discrepancy between a theoretical and practical approach.

The term "stakeholders" refers to all those involved in or influenced by management decisions (Ginige et al., 2018). A sustainable port necessitates several separate related parties that scarcely cooperate and behave as entities rather than as a team (Parola et al., 2018). Instead, they should collaborate on a shared objective to benefit everyone involved (Sifakis and Tsoutsos, 2021). A well-thought-out strategy must be pursued to convince them to cooperate on a shared goal. Implementing an energy strategy must satisfy the cost minimization criterion and environmental elements, both locally and globally, and incorporate multiple criteria and decision-makers (Del Giudice et al., 2017; Veronica et al., 2020). Consequently, it is reasonable to assume that conflicting interests and numerous goals will emerge (Diakaki et al., 2013; Foster et al., 2017). Innovative public transportation concepts are required to drive long-term change in the public transportation sector while minimizing significant structural investments (Sindakis et al., 2015). Knowledge management requires excellent familiarity with the barriers and the associated best practices (Oliva, 2014). Individuals' attitudes and behaviors when engaging in knowledge management activities can be seriously influenced by an organization's effort to appropriate their information, resulting in tensions and losses in knowledge systems (Rechberg and Syed, 2013). Several strategies can be incorporated to handle knowledge management, mainly by making different parties collaborate and creating a higher knowledge base that is exploitable in the future (de Marchi and Grandinetti, 2013; Scuotto et al., 2017). Digitalizing data and system mapping can prove helpful for strategies that lead to transparent and substantial outcomes (Nikas et al., 2017).

It has been studied and revealed that firms' internal skills are linked closely with external knowledge accessed through partnerships with external partners (Scuotto et al., 2017).

According to recent studies, if small enterprises are concerned about sustainability, all related projects should be incorporated into their overall missions and policies to bring value to their activities rather than hinder them. Environmental sustainability encourages companies to shift away from traditional operations by significantly changing their corporate processes, enabling them to accomplish financial and social targets. Small firms find it difficult to embrace such improvements because of their capital resource limitations (Del Giudice et al., 2017).

The importance of involving the local population in decision-making has become increasingly significant (Wamsler, 2017b). The stakeholders' attitudes towards the management should be recorded to map their existing relations and help reduce conflicts. The primary purpose is to promote the main stakeholders' consensus, participation, integration, and cooperation (Butowski, 2018).

Previous studies have examined the most available interventions for transitioning from ports to sustainable ports. However, the wide variety of tools and technologies found in this study argues that the literature is unlikely to adequately support port decision-makers in prioritizing different emission reduction measures, as there are few empirical results from ports. Moreover, problems caused by the operation of both ships and ports can help classify the environmental objectives using a multi-criteria analysis approach.

Multi-criteria research methods have also been utilized to assess European coastal and offshore areas for sailing tourism (Butowski, 2018). Multiple parameters that include the social dimension of such an initiative have shown that social acceptance is one of the leading (Torres-Machi et al., 2017). Social factors are considered less concerning regarding economic and environmental dimensions (Missimer et al., 2017). Furthermore, it is notable that some public projects still need to adequately examine social dimensions, raising the issue of socioeconomic success a significant concern for the time being (Torres-Machi et al., 2017).

Ports connect maritime and inland transport, local inland and outer land, various transport and transport facilities, and the commercial and urban system in which the port is situated. To understand the port operation and management, the involvement of stakeholders is of great importance (Lam et al., 2013). The need to increase stakeholder engagement and structured

participation in infrastructure projects has been widely recognized by the availability of significant research projects in this area (Bickerstaff et al., n.d.).

A matrix to clarify economic and social performance relationships based on the principles of stakeholder heterogeneity has been established, showing that different economic and social performance relationships can vary with the roles of various stakeholders in the sustainable problems of ports (Cheon, 2017). Building partnerships with stakeholders is crucial for effective strategies in the maritime port areas (Ha et al., 2019; Notteboom et al., 2015). Stakeholder management helps port managers coordinate all interests to establish accepted and supportive priorities and business plans for long-term success (Freeman et al., 2004). Port management can be understood as achieving the long-sought-after dialogue among stakeholders on their disparate goals and competing interests (Parola and Maugeri, 2013). Until recently, the design and implementation of energy policies was a centrally controlled decision-making process, the primary purpose of which was the satisfaction of energy demands at the lowest cost. It has been recognized that more than such an approach is needed to address the complexity of modern energy problems (Geels et al., 2018).

To achieve continuous improvement, stakeholder satisfaction must be strongly considered. In other words, any improvement action should be examined with stakeholders' needs, desires, and expectations in mind (Manolitzas et al., 2018). Hence, any methodological tool should address such factors to facilitate decision-making (Wątróbski et al., 2019). This requires the creation of a methodological decision-making framework that can incorporate all these criteria. Multicriteria analysis (MCA) offers a structural framework to model energy and environmental planning (Nikas et al., 2018).

## **5.3 Methodology**

### **5.3.1 Mathematical tools and models**

Multi-criteria decision Analysis (MCDA) is a capable tool in policy design (for designing a policy), considering many criteria that functionally incorporate conflicting goals while including team decision-making processes (Tsoutsos et al., 2009). The use of MCDA techniques presents a long history of energy planning. It provides a complete and valid methodological framework for evaluating, categorizing, and selecting energy projects (Strantzali and Aravossis, 2016), thus



facilitating the determination of appropriate environmental management practices (Fatemi and Rezaei-Moghaddam, n.d.).

In today's rapidly evolving and interconnected world, the need for MCDA has become more pronounced than ever. Many of the complex decisions we encounter involve a multitude of criteria, each with its own unique set of values and objectives. Whether selecting the most cost-effective renewable energy project, evaluating public policies that balance economic growth and environmental sustainability, or deciding on investments that consider both short-term returns and long-term impact, traditional decision-making models often need to catch up in accounting for these diverse and interrelated factors. Multi-Criteria Decision Analysis (MCDA) offers a structured and systematic approach to address these multifaceted challenges. It empowers decision-makers to quantify and assess the trade-offs between criteria, enabling a holistic perspective that aligns choices with stakeholders' broader objectives and values. Moreover, MCDA contributes to transparency, accountability, and robust decision-making. Explicitly defining criteria and their relative importance allows decision-makers to communicate the rationale behind their choices to stakeholders, promoting transparency. This, in turn, enhances accountability, as it becomes clear how and why specific decisions were made. Furthermore, MCDA offers a rigorous methodology for evaluating alternatives, reducing the risk of subjective or biased decision outcomes. It provides a framework that can accommodate qualitative and quantitative data, ensuring that decisions are grounded in a comprehensive understanding of the problem, ultimately leading to better, more informed choices in an increasingly complex world.

### **5.3.2 Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE)**

The PROMETHEE is a widely utilized multicriteria decision-making (MCDM) methodology designed to assist individuals and organizations in making well-informed decisions when faced with complex choices. Introduced by Belgian researchers Brans and Mareschal in the early 1980s, PROMETHEE has gained popularity in various fields, including business, engineering, environmental management, and healthcare. This method offers a systematic and structured approach to evaluating alternatives based on multiple criteria, allowing decision-makers to prioritize options according to their preferences and objectives.

In the context of PROMETHEE, the methodology's flexibility and adaptability make it well-suited for incorporating objective and subjective criteria. PROMETHEE allows decision-makers to define and structure the criteria used in the decision process, and these criteria can encompass a wide range of characteristics, from quantifiable, objective data to more qualitative, subjective factors. This versatility is invaluable when addressing multifaceted decision problems.

PROMETHEE uniquely accommodates both objective and subjective criteria. Objective criteria such as cost, profit, or environmental emissions can be quantitatively measured. In contrast, subjective criteria involve decision-makers' judgments, preferences, and opinions, which often need to be more straightforward to quantify. Incorporating objective and subjective criteria in PROMETHEE enables a more comprehensive assessment of alternatives. The method accommodates this diversity by allowing decision-makers to assign appropriate weights to each criterion based on their relative importance.

PROMETHEE's ability to provide a structured and transparent process for incorporating these criteria ensures that the final decision is well-balanced and aligns with the decision-makers and stakeholders' preferences and objectives. This approach promotes better-informed decisions and fosters greater acceptance and understanding among those involved in the decision-making process.

Following the main steps of PROMETHEE are described:

**Step 1:** The PROMETHEE framework begins with defining and structuring the decision problem. This stage involves identifying the criteria and alternatives relevant to the decision context. Criteria represent the aspects that must be considered during the evaluation, and alternatives are the options or solutions for selection. Defining these elements is essential to clarify the scope and objectives of the decision.

**Step 2:** In this step, decision-makers systematically compare criteria and alternatives, expressing their preferences through preference values. These values capture the relative importance of criteria and the performance of other options concerning each criterion. This pairwise comparison process provides valuable data that will be used to establish a preference matrix, which serves as the foundation for subsequent calculations.

**Step 3:** PROMETHEE employs a set of preference functions to model and quantify the decision-maker's preferences based on the data collected during pairwise comparisons.

**Step 4:** Finally, PROMETHEE ranks alternatives based on their preference scores, providing decision-makers with a clear and systematic way to prioritize options. The results allow for exploring different scenarios by adjusting criteria weights.

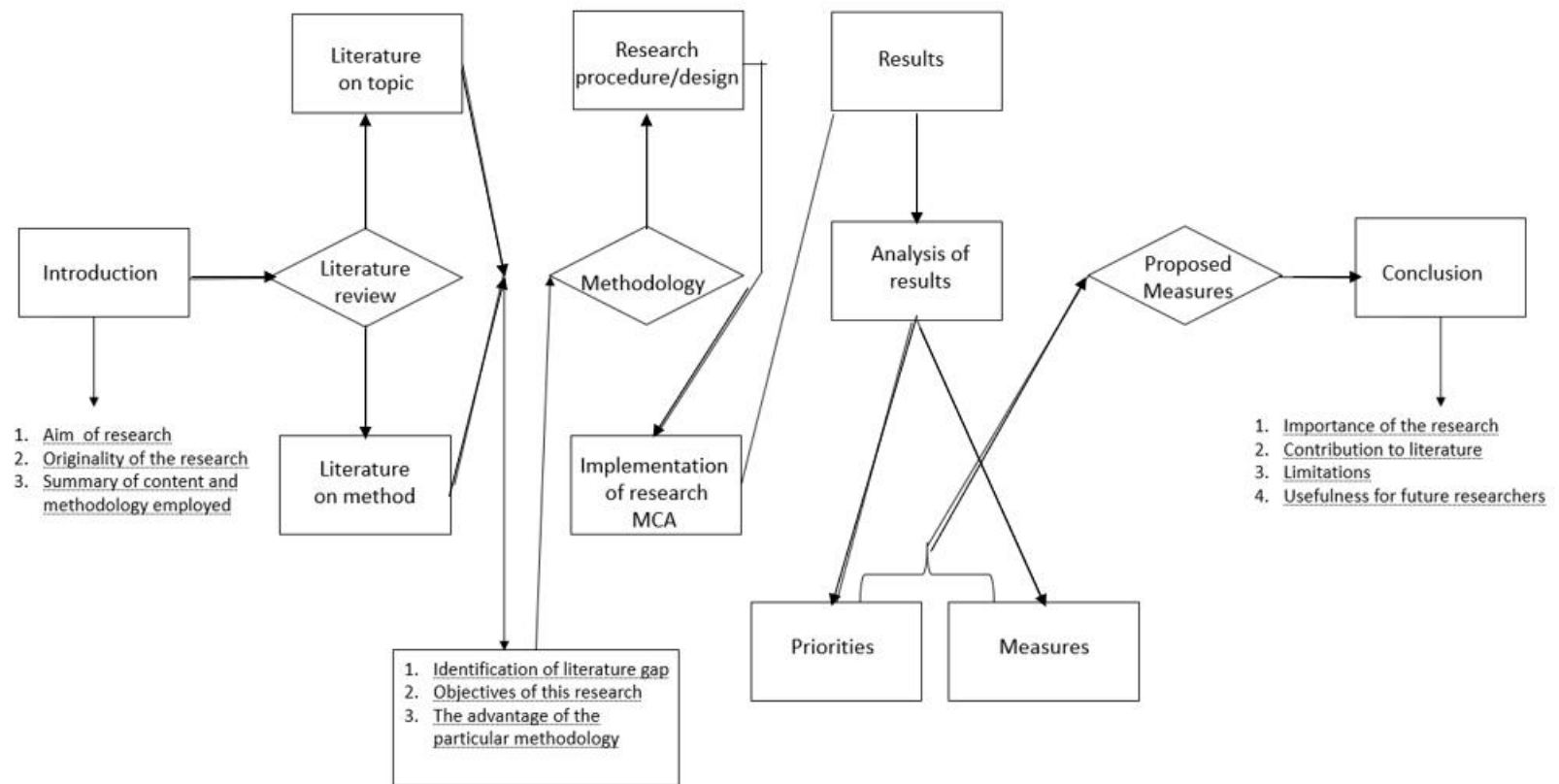
In the context of the PROMETHEE methodology, "PHI," "PHI+," and "PHI-" represent three key concepts used to compare and rank alternatives based on their preference values. Here's a natural description of these concepts:

**PHI ( $\Phi$ ):** PHI represents the net preference value of one alternative over another for a specific criterion. It is a quantitative measure indicating the strength and direction of preference for one option compared to another on a particular criterion.

A positive PHI value ( $\Phi > 0$ ) suggests that the first alternative is preferred over the second for that criterion. A negative PHI value ( $\Phi < 0$ ) indicates that the second alternative is chosen over the first for that criterion.

A PHI value of zero ( $\Phi = 0$ ) implies no preference between the two alternatives on that criterion.

Essentially, PHI, PHI+, and PHI- are essential components of PROMETHEE used to calculate and represent alternative preference values. They help generate rankings by capturing the net preferences for each alternative, facilitating the identification of the most and least preferred options in multi-criteria decision-making scenarios.



**Figure 5.1** Stages of the proposed methodology

### **5.3.3 Profile of the respondents' panel**

Our research was based on analyzing the results derived from answers from 50 experts and relevant stakeholders. These were selected randomly by a wide range of categories of stakeholders (Table 5.1). Besides, the responses were collected within two weeks, so they were based on a specific momentum. The limited period was intended so the stakeholders would not be affected by various incidents that could change their opinions. The survey results can be considered reliable as its sample consisted of a statistically sufficient number of completed questionnaires (50). It can also be valid as covering a broad professional, social, educational, and age spectrum. Initially, the respondents were asked to rank the 12 criteria in a row, wrt a scale ranging from 10 = fundamental criterion to 1 = minimal/irrelevant criterion. Besides, ranking them in the same position was possible if one judged that some criteria carried the same weight. The data collection process occurred for approximately three months (early February to late April - the period for all groups - in 2019). The Souda port was chosen as the study area. The selected categories and subcategories of stakeholders are listed below, as well as the exact number of participants per subcategory.

**Table 5.1.**Profile of the respondents' panel

	Categories	Subcategories	Number of applicants	Number of
1.	Local authorities	Municipality	3	5
		Regional	2	
2.	Shipping Operators	Shipping lines	1	4
		Shipping Agencies	2	
		Towage and pilotage	1	
3.	Tourism sector	Travel agencies	3	5
		Tourists	2	
4.	Transport operators	Private bus	2	3
		TAXI	1	
5.	Academic/ research institutions	Technical University of Crete	3	4
		Mediterranean Vocational	1	
6.	Employees	Dockers	1	9
		Fishermen	2	
		Pilots	2	
		Marine engineers	2	
		Crew members	1	
		Port Facility Security Officer	1	
7.	Suppliers	Fuel suppliers	1	3
		Ship chandlers	2	
8.	Government Organization	Coast Guard Authority	3	6
		Customs	1	
		Police	1	
		Fire Brigade	1	
9.	Local Community	Residents	3	6
		Merchants	1	
		Students	2	
10.	Private Sector	Crane Companies	1	5
		Load transportation companies	2	
		Anti-pollution companies	1	

The integrated approach must include various technological, energy, environmental, economic, and social criteria. Such criteria in the present research are, among others, optimizing the use of available resources, minimizing environmental impacts, reducing overall costs, enhancing operational safety, and meeting energy needs (Gomes Correia et al., 2016). The survey questionnaire, answered by the stakeholders, was divided into four distinct areas (environment, economy/tourism, social acceptance, and technology).

Port operations are a critical lever for attracting new investments that contribute to companies' human resources and profit growth (Kuo et al., 2020), as well as tourism development through the modernization of the facilities and the upgrading of the ports' infrastructure. Thus, participants evaluated the criteria of tourism-related services, local/regional economy, and competitiveness to determine their degree of severity as conducive to the economic impact of a port.

The reference to social criteria involves all the parameters that affect the social structures, relationships, and actions of the development area and reflect the extent to which the community or a group accepts a situation or activity upon recognizing its advantages and disadvantages (Balbar and Metaxas, 2019). Hence, the study's social criteria were chosen for the degree of local acceptance, employment opportunities, personnel safety, and the services provided.

Using technology in port operations can significantly enhance its overall performance, safety, and security functions and environmental impact, even more so via sustainable solutions, such as waste management (Di Vaio et al., 2019) and renewable energy use (Zharan and Bongaerts, 2017). To measure the study area's technological assessment, such criteria as easy-to-use technological applications, efficiency, and technology maturity were employed, the combination of which required the correlation of a series of data, expert opinions, empirical knowledge, and practical rules to be dealt with.

## **5.4 Results**

### **5.4.1 Specific Criteria Weights**

All the groups' choices/answers have been classified, with one being the most important and ten being the least important. Then, the average values per criterion in all groups were determined. As mentioned, the work aimed to explore the appropriate measures for designing an energy-viable green port by studying the relevant bibliographical references and the groups' preferences for a particular area, such as the CHA.

The weights were calculated based on the questionnaires' answers and consecutive analysis. Table 5.2 lists the resulting number for each criterion per stakeholder category and the total weight per criterion (%), considering all the stakeholder groups. The last column of the table shows their ranking, starting from number 1, which declares the first criterion of importance, and ending with number 13, which indicates the least important.



**Table 5.2.** Relative weights of participant factors wrt participants' groups

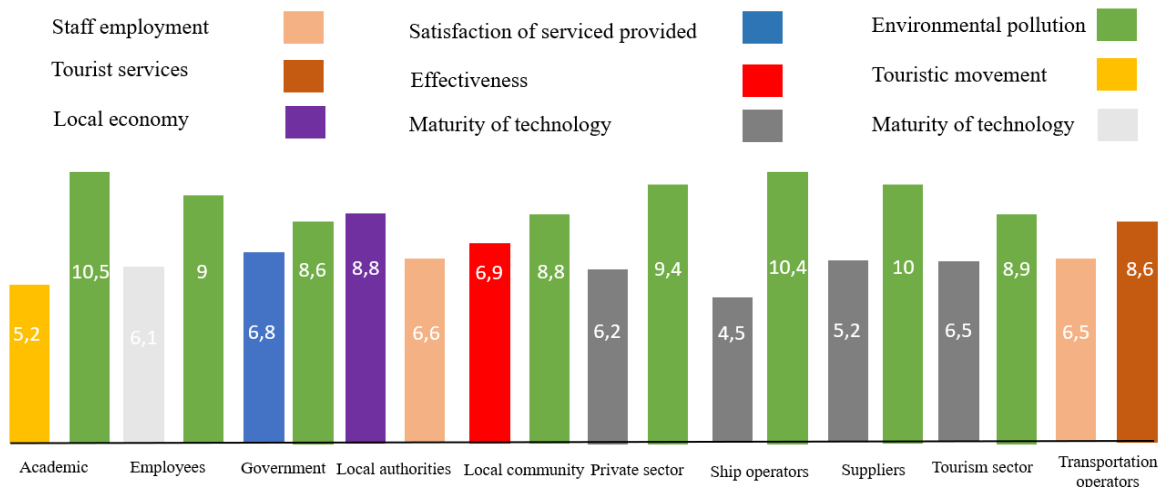
Stakeholders Criteria	A&R I <sup>1</sup>	E <sup>2</sup>	G O <sup>3</sup>	L A <sup>4</sup>	L C <sup>5</sup>	P S <sup>6</sup>	S O <sup>7</sup>	S <sup>8</sup>	T S <sup>9</sup>	T O <sup>10</sup>	Average weight	Classification criteria
Environmental pollution	<b>10.5</b> <sup>11</sup>	9	8.6	<u>7.2</u>	8.8	9.4	10.4	10	8.9	8.5	9.1	1
Staff/Infrastructure security	8.1	8.9	<u>7.8</u> <sup>11</sup>	8.7	7.8	8.8	8.8	<b>9.6</b>	8.9	8.2	8.6	2
Energy	<b>10</b>	8.8	<u>7.3</u>	7.4	8.1	8.5	9.3	8.9	8	6.8	8.3	3
Security of the services provided	<u>7.1</u>	7.6	8.1	<u>7.7</u>	7.4	8.5	<b>8.8</b>	8.6	8.3	7.9	8	4
Tourist services	<u>6.8</u>	7.9	7.9	7.4	8.1	7.7	8.2	8.2	8	<b>8.6</b>	7.9	5
Competitiveness	<b>8.6</b>	7.6	7.3	8.5	<u>7.1</u>	7.7	7.7	7.6	8	7.9	7.8	6
Local / Regional Economy	8.1	7.3	7.3	<b>8.8</b>	<u>7.1</u>	7.2	8.5	7.9	7.6	7.6	7.7	7
Satisfaction of interested parties with the services	<u>6.3</u>	7.9	6.8	8.3	8	7.9	7.7	7.9	8	<b>8.6</b>	7.7	8
User-friendly technological applications	7.3	6.4	8.4	7.4	<b>8.1</b>	7.5	<u>5.6</u>	6.2	7.1	7.9	7.2	9
Tourist movement	<u>5.2</u>	<b>8.3</b>	6.9	7	7.4	7.2	7.4	7.6	7.2	7.9	7.2	10
Staff employment	6.8	<b>7.8</b>	7.6	6.6	7.8	6.8	7.2	<u>6.5</u>	7	<u>6.5</u>	7.1	11
Effectiveness	<b>8.4</b>	6.4	7.9	7.4	6.9	6.6	5.9	<u>5.8</u>	6.5	6.8	6.9	12
Maturity of technology	6.8	6.1	<b>8.1</b>	7.6	7.4	6.2	<u>4.5</u>	5.2	6.5	6.8	6.5	13

<sup>1</sup>Academic/research institutions; <sup>2</sup>Employees; <sup>3</sup>Government Organization; <sup>4</sup>Local authorities; <sup>5</sup>Local Community; <sup>6</sup>Private Sector; <sup>7</sup>Shipping Operators; <sup>8</sup>Suppliers; <sup>9</sup>Tourism sector; <sup>10</sup>Transport operators; <sup>11</sup>The minimum value given to a criterion per group is underlined, and the maximum value assigned to a criterion per group is in bold.

Table 5.2 indicates that 9 out of 10 respondents' groups rated environmental pollution as number one, with a score of over 8.5. 5 out of 10 attributed the same rating to staff security, 4 out of 10 to energy, and 3 out of 10 to protect the services provided. From the above, it is evident that in the case of Souda port, the most important priorities are environmental pollution, staff safety, energy, and security of services. Based on these results, it seems that the key priorities of this research (environmental pollution and energy) coincide with the critical importance of the European Sea Ports Organization (ESPO) research, attesting to the study's credibility. The top 10 environmental priorities of European ports for 2018, according to ESPO (Seguv et al., 2016), are the following in Figure 5.2:



**Figure 5.2** The top 10 environmental priorities of European ports for the year 2023

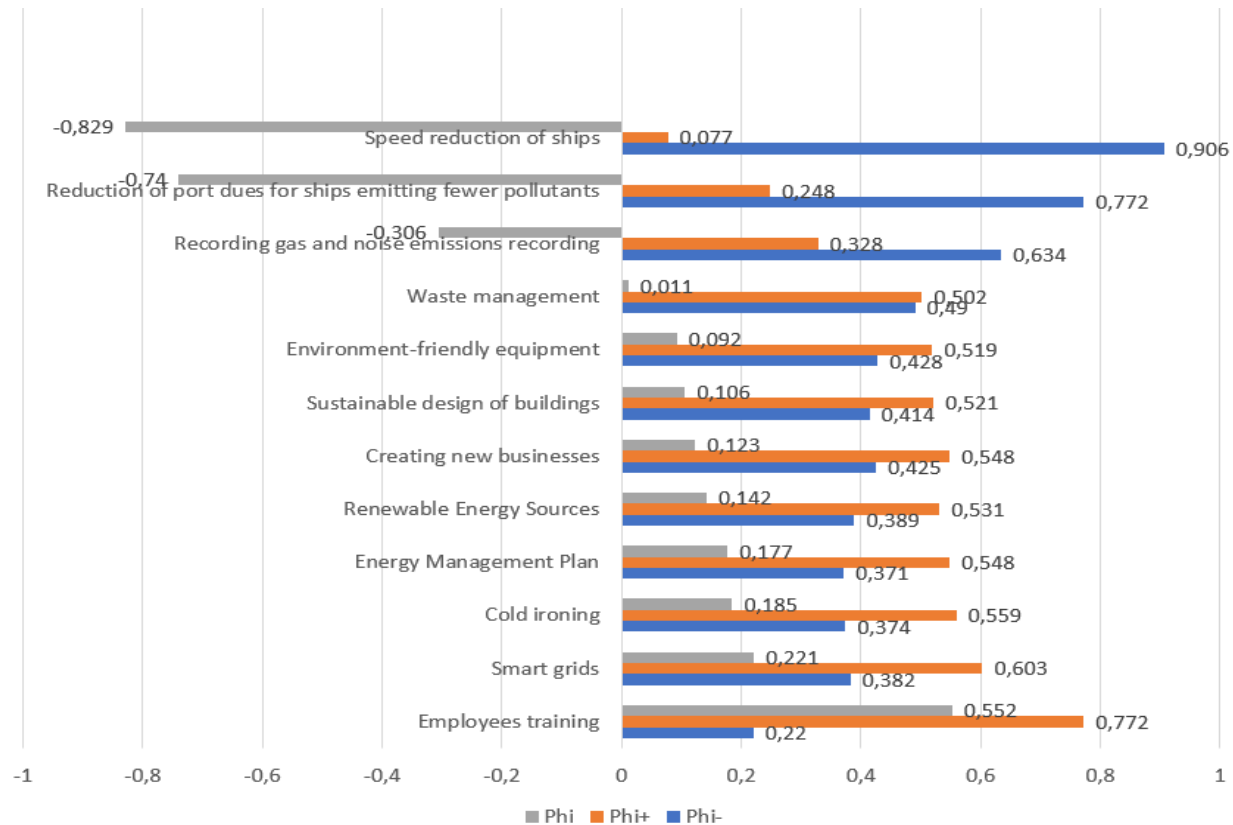


**Figure 5.3.** Maximum and minimum scores for each sector

According to Figure 5.3, environmental pollution, the local economy, and tourist services were the most crucial criteria for many stakeholders. Technology maturity was ranked as the least important. Technologies are characterized by great diversity varying in maturity. Many of the existing and promising technologies need to be utilized. Factors such as stakeholder commitments to current technologies or the cost of new investments contribute to this. In addition to identifying the criterion of technological maturity, it is also observed that to render it more favorable, educational and training policies need to be improved to develop workers' ability to adapt to new technologies and use them appropriately.

The research results through the PROMETHEE software for environmental planning are presented in

shows the Phi, Phi+, and Phi- values for all proposed measures ranked according to the evaluation.



**Figure 5.4.** PROMETHEE II phi values

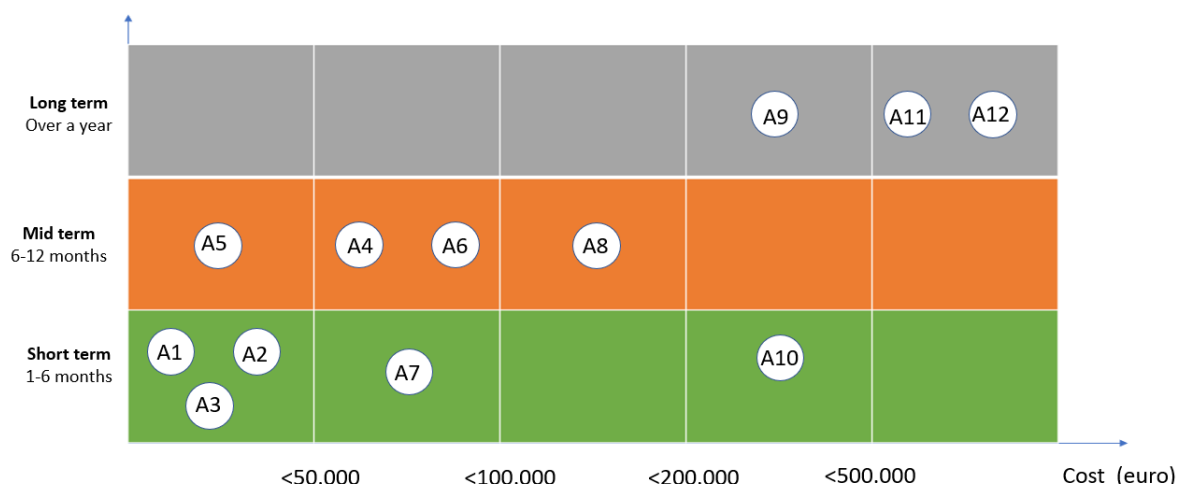
All groups ranked according to the net Phi value, with staff training as the most appropriate measure and reducing ship speeds as the least relevant. However, observing the Phi+ value, staff training is first, with smart grids second, generation power supply third, and ship speed plummeting last. The reduction in ship speed is attributed to the lowest value of  $\text{Phi}^+ = 0.077$  in all groups. Concerning the positive amount of Phi +, the staff training measure re-recorded the highest value, proving and verifying it as the most appropriate action. At the Phi- value, the deceleration of ships is ranked first at an index of  $\text{Phi}^- = 0.906$ , the highest negative value. This shows the need for improvement of this system or even its low preference. According to data analysis, the reduction of port charges, gas and sound recording, and waste management are lower on the Phi-rank.

By conducting a qualitative analysis of the results in Figure 5.4, we can safely conclude that staff training for skills building is the most critical measure. A Sustainable development culture can address society's need to modify its perspective on life through a process that will lead to change. Environmental education and training are essential so that stakeholder management is constructive for the decision-making process and implementation of these decisions in the future (Karataş and Karataş, 2016). Such training promotes social participation, enhances people's relationships, and develops a fair and rational society. In this, environmental knowledge contributes to environmental understanding and awareness.

On the other hand, the least-rated measure is reducing ship speed. Slowing down the pace of ships will cause delays to vessels, negatively impacting trade profits. The research results show that the environmental footprint can be improved by measures that, although contributing to improving environmental indicators, will not affect the port's proper commercial and touristic operations.

#### **5.4.2 Implementation Timeframe of Actions/Cost/Impact**

The policy measures presented have different implementation time frames. Some can be implemented in the short term, while others require a longer time horizon (medium to long term). Figure 5.5 shows the implementation time frame per action presented in the previous section, the estimated cost, and some advantages and disadvantages. It shows the hierarchical time of implementation, listing the actions that can be implemented in the short term in the first place and then those that can be implemented in the medium and long term based on their implementation costs.



**Figure 5.5.** Implementation Timeframe of Actions/Cost

A1: Reduction port dues, A2: Recording gas and noise, A3: Waste management (plan and equipment), A4: Speed reduction, A5: Employees training, A6: Smart grids, A7: Energy management plan, A8: New business, A9: Sustainable design building, A10: Environmentally friendly equipment (i.e. transportation), A11: Renewable Energy Sources, A12: Cold ironing

According to Figure 5.5, the promotion of port charges reduction (A1), waste management (A3), and the recording of environmental gases and sound (A2) are measures that are feasible and mature both in the short term. Some of these measures have already been implemented in the CHA. Others can be realized as quickly as possible with limited funding and without any legislative framework. The reduction in ships' speed (A4) can be achieved over a medium-term period, as it requires the study of the adverse effects of any delay in service.

Employee training (A5) may be implemented directly through initiatives of local authorities and other bodies but is expected to mature after a reasonable period, which is necessary to consolidate newly gained information and knowledge by its recipients. In this context, its results are estimated to be visible in a medium to long-term period.

Promoting sustainable building design (A9) that can deliver positive results to new buildings in terms of their energy identity will also bear fruit in the long run.

Using environmentally friendly equipment includes such actions as using means of transport (electric buses), which improve the environmental footprint and reduce energy consumption. The utilization of RES (A11) and cold ironing (A12) are actions that cannot produce visible results in the short term, as such interventions can be implemented by resources either managed by local authorities or allocated by individual bodies/parties, which the high cost might deter. Nevertheless,

these actions will significantly contribute to implementing a green and competitive port. Table 5.3 shows the advantages and disadvantages of each action. Most actions considered can improve port sustainability without significant drawbacks.

**Table 5.3.** Advantages and disadvantages of each measure

Actions	Advantages (+) / Disadvantages (-)	
Reduction port dues (A1)	+	Environmental footprint
	+	Quality of life
	-	Reduced income
Recording gas and noise (A2)	+	Environmental footprint, Noise reduction
	-	
Waste management (plan and equipment) (A3)	+	Environmental footprint
	+	Quality of life
Speed reduction (A4)	+	Environmental footprint
	-	Less competitive
Employees training (A5)	+	Environmental footprint
	+	Awareness of environmental issues
Smart grids (A6)	+	Environmental footprint
	+	Energy consumption
Energy management plan (A7)	+	Environmental footprint
	+	Energy consumption
New business (A8)	+	Environmental footprint
	+	More competitive
Sustainable design building (A9)	+	Environmental footprint
	+	Energy consumption
Environmentally friendly equipment (A10)	+	Environmental footprint
	+	Energy consumption
Renewable Energy Sources (A11)	+	Environmental footprint, Increase Income
	-	High cost
Cold ironing (A12)	+	Environmental footprint
	-	High cost

## **5.5 Conclusions, implications, and future recommendations**

Based on the challenges regarding optimizing port sustainability, the present work focuses on developing guidelines to facilitate and promote stakeholder cooperation. A special questionnaire was designed to elicit answers from various port stakeholders. Then, a 'multi-criteria analysis' process was applied, focusing on the goals of specific criteria, such as climate and energy, and steps to optimize the sustainable indicators.

The data evaluation showed that the key priorities for port sustainability are environmental pollution, the security of staff and facilities, and energy. Training employees and introducing innovative energy grid systems have been rated as the most successful strategies for achieving climate and growth targets in the context of the actions studied. We encountered barriers during our study, such as the small number of published papers that discuss the joint effects of environmental factors, cost, and the time required to implement the measures. In addition, due to the specialized purpose of the research questions, a number of the involved individuals needed help to answer certain questions. The challenge was addressed through the conduction of sample interviews. The current research findings can be used for further analysis based on the relationship between the private and public sectors, both in the planning-implementation process and in the funding phase, to incorporate the acts.

## **Chapter 6- Navigating the Port of Sustainability: Citizens' Perspectives and Challenges Explored**



## 6.1 Introduction

Nowadays, the need for ever-greater transport of goods through maritime trade is the driving force behind optimizing port management and efficiency (Attia, 2016). Due to globalization, these new marine transport requirements have created new port data for their management (Hlali and Hammami, 2018). However, the rapid development of ports has resulted in environmental degradation and social and economic problems (Lam and Yap, 2019). Many international ports are already implementing measures to meet modern needs and requirements. Although the shipping industry is widely regarded as one of the least environmentally detrimental modes of transportation, it faces significant risks due to the scale of shipping and port operations (Peris-Mora et al., 2005). In this context, the need to protect the environment has forced the port industry to adapt its services to enhance competitiveness (Molavi et al., 2020).

In recent years, changes in EU policy and the international community have led to improved ports in all areas that are efficient and competitive and fully meet the demands of modern trade (Lim et al., 2019). Although implementing integrated sustainable management in ports is extremely important, it is only sometimes feasible to apply it directly but gradually by integrating parameters into each activity to render them viable regarding social, economic, and environmental sustainability.

Adopting and implementing integrated policies for sustainable development at both European and global levels are becoming imperative. Since the second half of the 20th century, the interaction between economic growth, social development, and environmental protection has been evident. The world community has recognized the importance of achieving these three goals in a balanced way to secure long-term global growth, where both present and future generations will enjoy decent living standards (Zhang and Ravesteijn, 2019). Notwithstanding the burgeoning research, significant weaknesses have been identified that hinder ports' development (Bergqvist and Monios, 2019).

Research on the marine environment in the context of sustainable development is more relevant than ever, a fact that has attracted the attention of many researchers. However, although researchers and policymakers have focused on quantifying sustainability, a limited number of studies have been conducted on the quality that focuses on the organizational challenges for implementing appropriate measures. To fill this need, this study proposes a methodology for improving port sustainability through specific actions, highlighting the necessity of citizen collaboration.

Furthermore, many surveys aim to study the perspectives of stakeholders involved in policy and decision-making processes to achieve sustainability goals. The term "stakeholders" might refer to an individual, a group, or an organization affected by the proposed changes, such as shipping companies, store owners, local industry, local organizations, and social and academic institutions such as schools and universities (Kahane Professor et al., 2013). On the contrary, few surveys examine citizens' participation in planning and decision-making. While stakeholders usually represent organized group positions and have a collective interest, citizens are generally considered members of local societies who represent individual positions away from financial interests. Table 6.1. presents some advantages and disadvantages of the stakeholders'/citizens' involvement in decision-making.

**Table 6.1.** Advantages and disadvantages of studying stakeholders'/citizens' views

<b>Stakeholders</b>		<b>Citizens</b>	
<b>Advantages of exploring stakeholders' opinions</b>	<b>Disadvantages to exploring stakeholders' opinions</b>	<b>Advantages of studying citizens' opinions</b>	<b>Disadvantages of studying citizens' opinions</b>
May more effectively represent specific perspectives and interests because of experience and knowledge	Stakeholder selection may not reflect the relative diversity of views	Increase public legitimacy	Limited capabilities for the implementation and limitations of specific suggested solutions
Ability to provide more scientifically documented solutions	The choice of stakeholders can compromise the public legitimacy of a participation process	Increase diversity and pluralism	The large gap in opinions between social groups
They may influence authorities, decision-makers, administrators, and the broader political sector	Strong stakeholders may dominate		

In the present research, an attempt has been made to explore citizens' views on the sustainability of the port, examining the following aspects simultaneously (social, environmental, and economic). Moreover, it tried to highlight the weaknesses of ports towards zero energy transition as well as the improvement of environmental parameters and provide solutions by proposing measures where resource exploitation, investment direction, and technological development orientation are all harmoniously developed and respectful of human beings' needs (Sifakis and Tsoutsos, 2021). As the EU recognizes that citizen participation in the EGD is critical for policy legitimacy and public support for climate action, our research will try to answer which indicators are most significant and what measures need to be taken to improve sustainability indicators based on the citizens' opinions. The interaction between port administrators and citizens should be interactive, conversational, and built on trust to enhance public awareness and encourage them to perceive, understand, adapt, and accept the services and systems provided in a future port. Getting the citizens' points of view increases port productivity, boosts citizen participation, and empowers all citizens in the new environment (Spandagos et al., 2022).

Given the importance of the maritime industry in achieving the SDGs, the need for more relevant research on maritime-related topics is notable, as (Sciberras and Silva, 2018) stressed that no SDGs expressly address the maritime sector. In this context, the survey aims to analyze citizens' perspectives to provide solutions for the maritime industry about implementing the Agenda of the United Nations (UN) for SDGs.

The reasons taken into account for the involvement of citizens rather than the stakeholders in this survey were firstly boosting the citizens' views to be taken into account by the relevant bodies; in addition, highlighting that the participation of informed public increases the ability of citizens to deal with current and future problems; also, promoting the involvement of citizens as they feel that their opinion is made known and valued and that their community respects them, which in turn is conducive to their more active involvement in decision-making and implementation processes. Based on the citizens' opinions, our research will try to answer which indicators are most significant and what measures must be taken to improve them. More specifically, the questionnaire was employed to achieve the following research objectives:

- Investigate citizens' level of background information and awareness on sustainable development issues

Identify possible problems in implementing the suggested necessary measures and propose potential solutions.

The main scientific question for this survey was “What is the degree of response/acceptance by the citizens to the proposed measures for sustainable development of ports?”

The questionnaire in our study was designed around 31 questions deemed sufficient for the research objectives. In addition, these questions were prepared clearly and straightforwardly using the following types of questions: (a) multiple-choice questions, in which respondents were given a set of options to choose from, and (b) scaling or ranking questions, in which respondents were given the option of ranking the available answers on a scale using a given range of values (namely, in our case, the Likert scale). The particular questionnaire was distributed to 500 citizens (Appendix 1). KPIs were initially used to analyze the results. Then, using the Likert method, the question criteria were evaluated. Moreover, using the SPSS, the correlation between the different criteria on specific demographics was studied. Finally, a factor analysis method was applied by reducing the variables while maintaining as much information as possible.

## **6.2 Literature review**

The concept of "sustainability" is widespread. It is applied with the main aim of improving the current situation, where the exploitation of resources (environmental), the direction of investments (economic), the orientation of technological development (technical), and institutional change (socially) develop harmoniously and with respect both human needs and the environment (Ashrafi et al., 2019). In general, improving sustainability can lead to a better holistic image of the port.

In addition, the concept of the green port, as mentioned in this study, has aroused the interest of academics, especially marine economists, engineers, social scientists, and others with an interdisciplinary background. However, the barrier found while conducting a bibliographic search on the issue of green ports is the need for a universally acknowledged definition of what a green port policy is and what it entails. Its broad definition allows port authorities to include various tasks in their environmental goals. For this survey, it was decided to define the green port as “an environmentally friendly and sustainably developed port, which meets all environmental requirements” (Satir and Doğan-Sağlamtimur, 2018).

Many ports have adopted various environmental, social, and economic criteria to study and analyze different aspects of sustainability (Argyriou et al., 2022). These criteria mainly give citizens an

overview of the port situation, particularly indicating their strengths and weaknesses (Hossain et al., 2021). International and national regulations dictate the shipping industry's activities to minimize hazardous consequences. The European Green Deal (EGD) agenda, announced by the European Commission in 2019, established a strategy for addressing climate change and environmental challenges, as well as transforming the EU into a fair and prosperous society with a modern, resource-efficient, and competitive economy that is decoupled from resource use (European Commission, 2019). Moreover, the EU adopted the European Climate Law in 2021, which establishes a framework for assessing progress toward net-zero emissions by 2050 and intends to guarantee that all sectors of the business and society contribute to that objective (Janota et al., 2022). Furthermore, the European Commission introduced 'Fit for 55' in July 2021, a comprehensive package of legislative actions addressing climate, energy, land use, transportation, and taxation to ensure that EU policies are consistent with the EU's climate targets. Some of these projects are particularly relevant to the Blue Economy (Köhl et al., 2021).

Adopting the agenda of the United Nations (UN) for sustainable development and ratifying the 17 SDGs by all UN member states in September 2015 is considered a milestone for the international community. For the first time, a consensus has been reached between developed and developing countries for achieving universal sustainable goals (Bennich et al., 2020; Cetrulo et al., 2020). Together with the Paris Agreement on Climate Change, the 2030 Agenda provides a road map for a better future and a global framework for international collaboration on sustainable development in its economic, social, environmental, and governance elements. Continuous SDGs progress is critical for demonstrating the EU's commitment to and leadership in sustainable development. Therefore, our research highlights the strengths and weaknesses of a port in various sections and proposes solutions to improve SDGs.

Climate change and other human acts that harm the environment on land and at sea require citizens' active participation and rapid intervention. Changes in residents' and customers' attitudes toward more sustainable standards can be achieved through education, awareness-raising, environmental monitoring, and reporting, all of which significantly strengthen the economy. Consumer habits, attitudes, and lifestyles that can be changed through education can help the financial assessment (Glavič, 2020).

Several methodologies have been identified in the literature to increase competitiveness and improve customer service to enhance port sustainability. (Puig et al., 2014) using European

Performance Indicators to assess port authorities' environmental performance and monitor progress toward continuous improvement. They suggest that port authorities demonstrate compliance and continuous improvement through scientific data and measurement tools. Furthermore, one additional tool is European Resources Planning (ERP) (Chadhar and Daneshgar, 2018), where the majority of researchers found that ERP systems are urgent to strengthen the economy (Sislian and Jaegler, 2020).

(Tae YEO et al., 2015) investigated the relationship between port service quality and customer satisfaction at Korean container ports. This research showed that providing a high-quality port service is significant to consumer satisfaction. (Ha et al., 2017) posed the question, “How to design a PPM framework as a diagnostic instrument to aid decision-makers in analyzing port performance?”. The suggested PPM framework’s goal was to identify the most critical PPIs for each group of port citizens and create an effective performance evaluation tool.

Interviews with experts representing the port authorities and important stakeholders at Port Canaveral (Kodzi and Saeed, 2021) aimed to create a framework through which a current cruise port may include multiple stakeholder interests to realize its attractiveness. Dimitrovski et al. (2021) investigated stakeholder perspectives on the sustainability of coastal and marine tourism in cross-border zones of the Nordic coastal area using a mixed-method approach. The findings add to existing knowledge by considering the perspectives of cruise tourists (individual) and destination marketers and policymakers (organizational).

Considering existing research, a gap that can be filled is that activities and sustainability measures primarily focus on environmental issues, such as pollution (Alamouh et al., 2021). Another gap that our research aims to fill is that although researchers have used several methodologies to help port decision-makers propose tools and technologies based on stakeholders’ preferences for a transition towards sustainability, there is not a wide range of studies based on citizens’ preferences. Given the pressure on ports to maintain sustainable performance, including their role in sustainable development, and those above academic and practical gaps, this study aims to provide a framework to guide port designers in integrating sustainable ports into sustainable development.

Academically, the study incorporates advancements in port sustainability, including categorizing findings (actions and measures), developing a conceptual framework that establishes new relationships and perspectives on the subject, and proposing a methodology to investigate sustainable port actions further. From a practical standpoint, the study's findings are a

comprehensive instrument that guides port professionals and policymakers about various actions and sustainability measures. As a result, they may assess their progress, determine whether they are viable, and determine how to improve their implementation.

### **6.2.1 Social sustainability**

Social sustainability invokes decisions and projects that promote the overall improvement of society (Dobre et al., 2015). The philosophy for the everyday good and social responsibility actions is today the most comprehensive strategy that can guarantee long-term economic viability and, at the same time, prosperity for society. Realizing that there can be no survival and success expressed only through economic figures has changed society's expectations radically. Any work is judged based on financial results and social and environmental criteria (Dobre et al., 2015).

### **6.2.2 Environmental sustainability**

As mentioned above, ports are crucial in national and international transport networks. Therefore, it is evident that the indirectly and directly related functions and activities cause various complex environmental issues (Lim et al., 2019). The environmental dimension needs to promote actions for environmental management. More specifically, it calls for efforts to reduce emissions, promote environmentally friendly technology and renewable energy sources, and sustain initiatives for achieving environmental sustainability (Chel and Kaushik, 2018).

### **6.2.3 Economic sustainability**

European seaports are vital for the economy, as many goods are exported or imported into the European Union. Economic sustainability seeks to meet the needs of people in a way that preserves the natural resources and environment for future generations (Nikčević, 2019).

### 6.3 Proposed measures

According to the literature, proposed measures for improving sustainable indicators are mentioned in Tables 6.2-6.4.

**Table 6.2.** Measures to improve the social indicators.

Factors	Ways	Actions	Results	Bibliography
Social elements	Social participation	<ul style="list-style-type: none"> <li>• The right to information</li> <li>• Present the need for sustainability</li> </ul>	<ul style="list-style-type: none"> <li>• Train people so that they can substantiate their objections and propose alternative solutions.</li> <li>• Contribute to better environmental decision-making, facilitate complex problem-solving, safeguard the legitimacy of the process, and foster citizens' environmental awareness</li> </ul>	(Nitsenko et al., 2017)
	Motivations	<ul style="list-style-type: none"> <li>• Lower port charges</li> <li>• Reduced cost of tickets based on sustainability goals</li> </ul>	Willingness for participation/contribution	(Marbuah, 2019)
	Social development	New businesses due to increased passenger numbers	Better social conditions	(Nitsenko et al., 2017)
Information policy	Education	Information	<ul style="list-style-type: none"> <li>• Safety and security in new jobs</li> <li>• Benefits and disadvantages of sustainable growth</li> </ul>	(Pauw et al., 2015)



1

**Table 6.3.** Measures to improve the environmental indicators

Factors	Measures	Ports of implementation	Cost	Bibliography
(Case studies)				
Air quality	Replacement of obsolete technology	Barcelona (Spain), Koper (Slovenia)	Medium-High	(Zis, 2019)
	Cold ironing	Antwerp (Belgium), Hamburg (Germany)	High	(Zis, 2019)
	Reducing port dues	Los Angeles/ Long Beach (USA) /	No	(Winnes et al., 2015)
	Monitoring	Potland (USA), Antwerp (Belgium)	Low	(Toscano and Murena, 2019)
	Solar power	Rotterdam (Netherlands), Valencia (Spain)	Medium-High	(Bouman et al., 2017)
	Wind power	Mostyn (UK), Oostende (Belgium)	High	(Degraer, n.d.)
	Reduced ship speed	Los Angeles/Long Beach (USA)	No	(Gusti and Semin, 2018)
	Electric cars	Port of Barcelona (Spain), New York and	Medium	(Norsworthy and Craft, 2013)
	Electric cars	Barcelona (Spain),	Medium	(Maffei and Masullo, 2014)
Noise	Monitoring	Vancouver (Canada)	Low	(Sdoukopoulos et al., 2019)
	Noise walls and barriers	Vancouver (Canada)	Low-Medium	(Merchant, 2019)
	Box-type handling of bulk material	Ust-Luga Sea Trade (Russia)	Low-Medium	(Sdoukopoulos et al., 2019)
Dust	Wind-dust screens	Murmansk (Russia)	Low-Medium	(Sdoukopoulos et al., 2019)
	Smart Lighting	Long Beach Container Terminal in Los Angeles	Low-Medium	(Sdoukopoulos et al., 2019)
	Support via ICT systems	Antwerp (Belgium)	Low	(Kotowska and Kubowicz, 2019)
Waste management	Recycling	Helsinki, Igoumenitsa (Greece)	Low-Medium	(Beza et al., 2014)

2

**Table 6.4.** Measures to improve the economic indicators

Ways	Results	Bibliography
Lower municipal taxes for residents	Willingness to pay/contribute	(Cohen, 2019)
<ul style="list-style-type: none"> <li>Funding by government</li> <li>EU projects</li> </ul>	Increase competitiveness	(Malinauskaite et al., 2017)
Informing citizens about the advantages and disadvantages (e.g., aesthetic image) of new investments	Reduce expenses such as energy and water consumption	(Schipper et al., 2017)

### 6.4 Description of Sampling

Table 6.5 identifies the profile of the sample taken through random sampling (500 individuals). The data collection process occurred for approximately three months (early February to late April 2019). The selected categories and subcategories of citizens are listed below, along with the exact number of participants per subcategory.

**Table 6.5.** Profile of the sample

		% of responses
Sex	Male	76.6
	Female	23.4
Age	15-24	9.6
	25-39	32.6
	40-64	53.4
	>64	4.4
Job	Public/State	26.6
	Private employee	26.6
	Unemployed	5.2
	Freelancer	27.2
	Housewife	0.6
	Retired	7.0
	Student	6.8
	JHS	3.2
Level of education	HS	26.8
	BD	49.4
	MSc	15.6
	PhD	5.0
Residency	Permanent	85.6
	Non-permanent	14.4
Frequency of port visits	Up to 2 times	37.8
	2-4 times	26.6
	> 4 times	35.6
Reasons of visit	Personal	75.4
	Professional	24.6

Demographic data were used to examine the perspectives in several categories: age, educational level, and gender. Specifically, the research examines the relationships between age and environmental concern, values, attitudes toward environmental behaviors, awareness, knowledge, motivations, and intentions. Furthermore, it investigates sustainable perceptions concerning education and occupation to determine greater incentives for groups with weak sustainability perceptions. Other demographic data was utilized to check the research's shortcomings, such as the high number of replies from permanent residents instead of tourists. This is consistent with the fact that it was conducted during winter months when visitor traffic was low.

## **6.5 Methodology (Mathematical tools and models)**

### **6.5.1 Mathematical tools**

The research was quantitative and qualitative, exploiting a specially designed questionnaire. The questions covered indicators relating to society, the environment, and the economy. More precisely, the questionnaire consisted of four different parts. The first three sections assessed social, environmental, and economic sustainability, while the fourth looked solely at demographics. The research instrument used to study the questionnaire was the Likert scale.

### **6.5.2 Mathematical models**

#### **a. Key Performance Indicators (KPI)**

To ensure the priorities of public and social interventions to create a sustainable port, we first assessed the society's attitudes towards various problems so that the planned actions are compatible with the local framework and citizens' perceptions. The port quality assessment focused on three factors directly affecting the civilians' lives (social, environmental, and financial) and was carried out using a methodology based on creating/determining KPIs (Maskey et al., 2018). The indicators provide quantitative information on the existing port condition and the willingness and interest of the society in the new measures/actions to be taken to develop a green port.

The following equation calculates Each indicator, which refers to a specific variable,  $X_i$ .

$$KPI_{X_i} = \frac{\sum \text{weight}_j * \text{frequency}_j}{100 * \text{total number of answers for } X_i} \quad (1)$$

Studying one of these KPIs, Table 6.6 analytically depicts the number of answers for the social assessment question "Can the creation of sustainable port bring about positive results?", namely  $X_1$ , about the gender [Male (M), Female (F)].

**Table 6.6.** KPI computation for the question X<sub>1</sub> w.r.t gender

		Not at all	A little	Little	Much/A lot	Very much	Total	KPI
X <sub>1</sub>	Weight	0	25	50	75	100		
	Can the creation of a sustainable port bring about positive results?							
	M	13	21	62	179	108	383	0.73
	F	3	5	18	53	38	117	0.75
	T	16	26	80	232	146	500	0.73

The particular indicator (of X<sub>1</sub> w.r.t Male) is calculated as follows:

$$KPI_{X_i(M)} = \frac{\sum \text{weight}_j * \text{frequency}_j}{100 * \text{total number of answers for } X_i} = \frac{13 * 0 + 21 * 25 + 62 * 50 + 179 * 75 + 108 * 100}{38300} = 0.73 \quad (2)$$

X<sub>1</sub> refers to questions 1 and M: Male.

Similarly, the indicator of X<sub>1</sub> w.r.t Female is equal to:

$$KPI_{X_i(F)} = (3 * 0 + 5 * 25 + 18 * 50 + 53 * 75 + 38 * 100) / 11700 = 0.75 \quad (3)$$

These weights are compatible with the gender distribution in Greece's last official census population (Table 6.7).

**Table 6.7.** Gender and age distribution of the population of Greece (census 2011)

Sex	Number of Citizens		Percentage
	Male	5.303.223	49
	Female	5.513.063	51

So, finally, the KPI for the X<sub>1</sub> (gender) is equal to:

$$KPI_{X_1(G)} = 0.49 * 0.73 + 0.51 * 0.75 = 0.74 \quad (4)$$

The same method is applied to evaluate KPIs for each variable in the social, environmental, and economic section regarding demographic data (Table 6.8).

**Table 6.8.** KPIs related to gender and age

	Gender			Age				
	M	F	normalization	15-24	25-39	40-64	>64	normalization
Social								
Average	0.61	0.64	$KPI_{X_i(s)}=0.63$	0.62	0.61	0.63	0.58	0.61
Environment								
Average	0.45	0.46	$KPI_{(EC)}=0.46$	0.50	0.46	0.44	0.42	0.45
Economic								
Average	0.69	0.70	$KPI_{(ENV)}=0.69$	0.71	0.70	0.69	0.64	0.68

Finally, the KPI for the social assessment related to gender is calculated as the average of the KPIs of the variables of the social part w.r.t the gender:  $KPI_{(s)}=0.63$

Based on the above calculations, the environmental and economic assessment for the gender is

$KPI_{(EC)}=0.46$  and  $KPI_{(ENV)}=0.69$ , respectively.

#### **b. Software Package for the Social Sciences (SPSS)**

In sustainability monitoring, multilevel statistical techniques play an increased role as tools to assess and assist port policymakers. The main objective is to identify the most critical factors influencing the deterioration of natural ecosystems. The statistical analysis of the data obtained (questionnaire responses) was conducted using the SPSS v. 25.0 statistical packages.

#### **c. Factor Analysis**

Another step in our statistical analysis was the exploratory factor analysis aimed to reduce the dimension of the data and identify any latent variables (main factors) characterizing them (Maskey et al., 2018). Factor analysis for each of the three parts of the questionnaire (social, environmental, and economic) was employed. Such factors determine the basic structure of the correlations of a set of variables and create a subset of interrelated variables. The specific factors represent the dimensions of the data, while at the same time, the variables that compose them by definition show significant correlations between them. In practice, it is a data reduction technique to find common factors between a group of variables. This tool was utilized in our research to cluster different criteria and identify the port's primary issues. With this process, the main problems could be identified, and targeted solutions could be proposed.

## **6.6 Results**

### **6.6.1 Based on KPI**

#### **(a) Social assessment**

The social network should be the key priority to accomplish the parallel and balanced development of the three sustainability pillars. In this context, the research aims to answer how citizens would be satisfied with creating a sustainable port and suggest possible solutions to ensure maximum responsiveness. The survey results showed that citizens expressed high satisfaction with developing a green port (63.8%). More specifically, they expressed positive opinions about creating new jobs (63.6%) and better working conditions (58.6%). On the other hand, they assessed the section as very low regarding the public's information about the advantages/disadvantages of sustainable development variables (90% not sufficient).

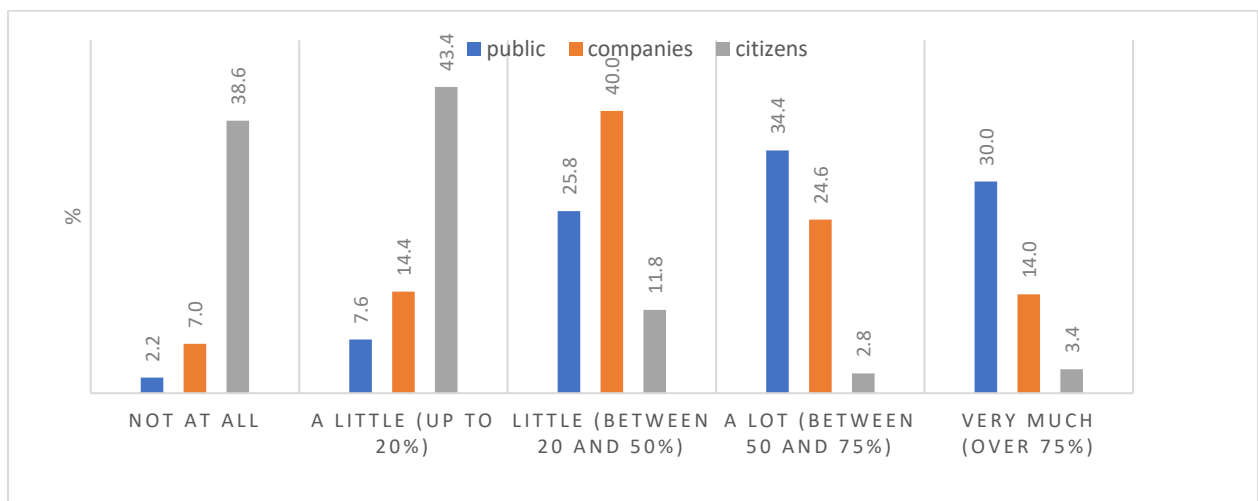
#### **(b) Environmental assessment**

The citizens assessed all indicators relating to the port's environmental footprint as relatively low, indicating that its picture is not satisfactory from an environmental point of view and that measures are needed to improve it. The sample granted the environmental indexes low (air pollution (31.4%), noise (27%), and dust (22.8%). The primary environmental problems of this port, like the ones of major international ports, are sea pollution (37.1%), waste management (50.6%), road quality (75.4%), and traffic (66%). A significant source of pollution is the ships (31.4%), the adjacent military port facilities (29.6%), and the traffic (22.4%). Another element highlighted by the environmental assessment survey is the endorsement of specific types of RES by citizens, such as solar (54.6%), wind (47.9%), tidal (41.8%), and biofuels (37.3%).

The results showed that all indicators relating to the low environmental footprint of the CHA were granted very low by citizens, indicating that the situation could be more satisfactory and that measures are needed for improvement. The assessment of environmental indicators, particularly in Section I of the questionnaire, suggests that port managers must take immediate action. This can be done with adequately planned activities based on good practices from other ports. In the case of section II, it is observed that the sources of pollution (facilities, vehicles, ships) have almost the same environmental impact. Another element highlighted by the environmental assessment survey in section III is endorsing specific types of RES by citizens, such as wind and solar. The plentiful sunshine and the strong area winds explain this. On the other hand, the choice of wave energy does not find suitable ground, and other studies have been done in Greece as this solution only thrives for some regions.

### (c) Economic assessment

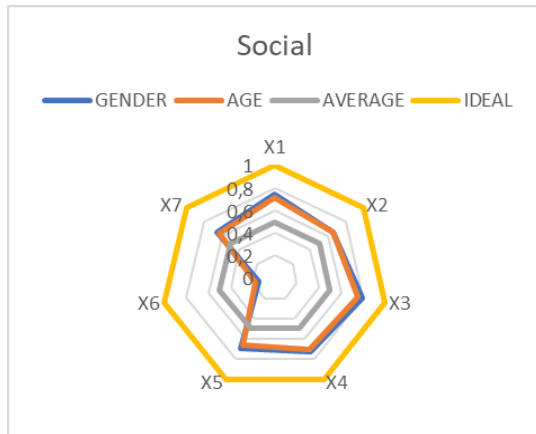
Investment is essential for enhancing the port industry. The survey examined economic evaluation factors such as investments in various environmental fields, the degree of involvement of public/private partnerships, and citizens' willingness to contribute financially to creating a sustainable port. The results revealed that several investment initiatives are needed in various areas of concern, such as traffic (75.8%), road quality (78.8%), sea pollution (75.2%), and waste management (81.6%). Additionally, many respondents believe that a public authority should make these investments with the support of shipping companies (Figure 6.1). In other words, most residents believe that, if not entirely, at least to a greater extent, port investment projects should be done and funded by the public, assuming that port management is public. However, some private sector participation should also be considered due to the high cost.



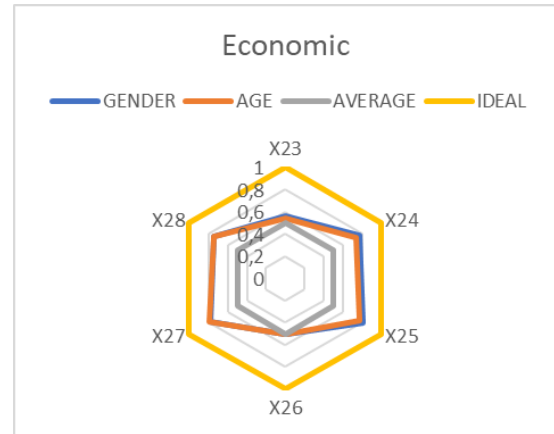
**Figure 6.1.** Financial contributors to the creation of a sustainable port

Another significant result revealed by the survey is the neutrality of citizens to contribute financially to creating a green port (71%). However, as neutrality is not conducive to any development, one objective of the survey was to suggest ways of re-sharing people's attitude approaches.

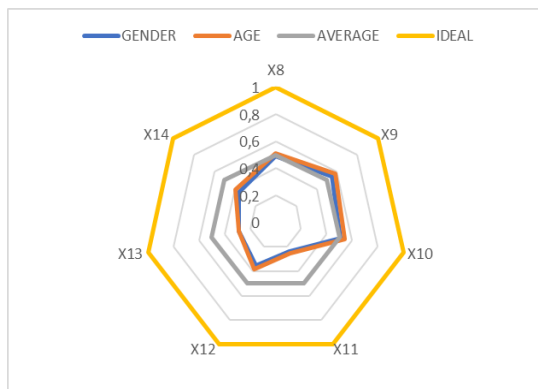
An illustrative analysis of these results is presented in the following radar charts demonstrating the values of the various KPIs about gender and age (Figures 6.2-6.4) and KPIs for each pillar of sustainability (Figure 6.5). The last figure demonstrates that the social parameter granted first, the environmental parameter second, and the economy later in creating a green port.



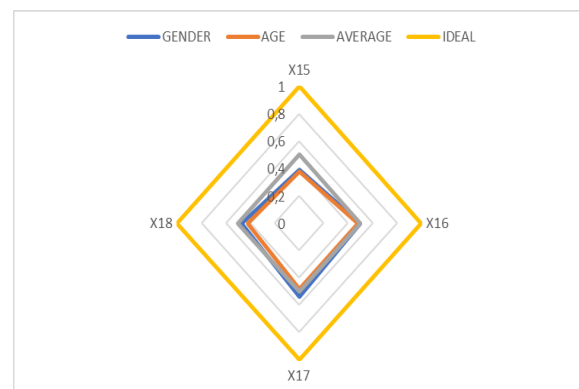
**Figure 6.2.** Social assessment KPIs



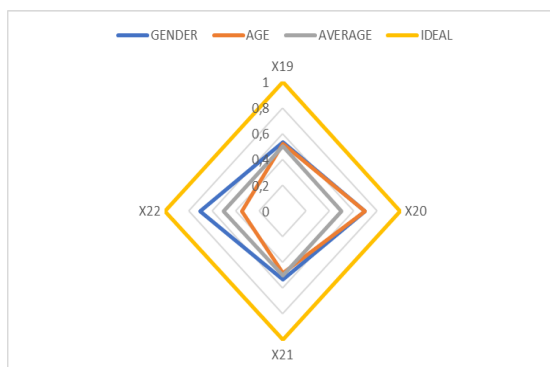
**Figure 6.3.** Economic assessment KPIs



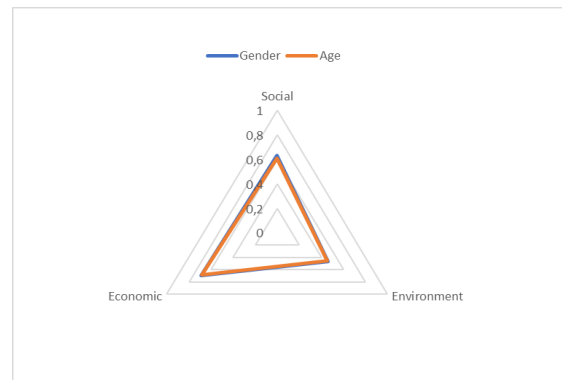
**Figure 6.4a.** Environmental quality indexes



**Figure 6.4b.** Environmental problems



**Figure 6.4c.** RES endorsement  
Sustainability



**Figure 6.5.** KPI values per  
pillar/part



### 6.6.2 Based on the Software Package for the Social Sciences (SPSS)

#### a. Gender

According to the literature, women are more concerned about environmental degradation (Collantes et al., 2018) and more committed to environmentally friendly behaviours such as recycling than men.

**Table 6.9. Chi-square tests w.r.t. gender**

<b>Environmental</b>				
	<b>men (%)</b>	<b>Women (%)</b>	<b>x<sup>2</sup></b>	<b>p-value</b>
air quality	15.9	30.0	15.593	0.004
dust	19.6	33.3	13.721	0.008
waste management	47.2	61.6	10.502	0.033
sea pollution	43.7	58.2	15.895	0.007
<b>Social</b>				
prosperity of area	70.5	85.5	20.028	0.000
<b>Economic</b>				
budget spend on pollution	36.8	48.7	19.811	0.008
traffic/parking spaces	77. 3	70.9	10.359	0.035

Women are more inclined toward developing a sustainable port, which coincides with the bibliography above (Table 6.9). Regarding the financial sector, women want to invest more money to deal with various forms of pollution, while men want to invest more money in traffic issues. This can be explained by the fact that most professionals at the port are men (i.e., truck/bus/taxi drivers, dockers, etc.).

#### b. Age

Age is another crucial demographic data correlated (statistically significant) with some social, economic, and environmental variables. The labor force group (ages 18-64) considers that creating a sustainable port will positively impact. The study of these elements is essential as it outlines the trends of the working population, which are crucial parameters in developing a future strategy. Another transparent element from the results is the correlation between age and social, environmental, and economic variables. These variables are assessed lower as the respondents' age increases (Table 6.10).

**Table 6.10.** Chi-square tests w.r.t. age

<b>Social</b>	<b>Age</b>				<b>x<sup>2</sup></b>	<b>p-value</b>
	<b>15-24</b>	<b>25-39</b>	<b>40-64</b>	<b>&gt;=65</b>		
	<b>(%)</b>	<b>(%)</b>	<b>(%)</b>	<b>(%)</b>		
positive results	14.6	23.9	36.3	13.6	25.104	0.014
better working conditions	20.8	28.2	31.8	4.5	21.459	0.044
<b>Economic</b> (budget spent on)						
air pollution	29.2	12.3	10.5	9.1	23.343	0.025
sea pollution	50.0	41.7	31.1	27.3	32.106	0.006
waste management	54.2	48.5	39.7	22.7	26.917	0.008
<b>Environmental</b>						
traffic pollution	20.8	28.2	36.3	36.4	27.951	0.006
ships' pollution	16.7	11.0	7.9	4.5	28.710	0.005
tracks/ vehicles pollution	14.6	9.8	6.7	4.5	22.057	0.037

### **b. Level of education**

(Ofei-Manu, 2015)believe that education is crucial to social-economic and environmental development with sustainability. The literature has widely recorded the positive relationship between education level and environmental awareness (Ampah et al., 2021). People with higher education are more concerned about the environment and more inclined to adopt environmental attitudes. Learning and teaching about environmental sustainability must occur not only in schools and higher education but across the system (formal, non-formal, and informal) and at all levels to reach its full potential (from early childhood to adulthood into older age). In this context, the European Commission has proposed an Environmental Sustainability Education Recommendation for students of all ages and levels of education through the EU Biodiversity Strategy and the Communication on the European Education Area (European Commission, 2022). This effort is a step towards assisting EU countries in developing more robust policies for environmental sustainability, climate education, biodiversity, and other relevant issues through collaboration. Moreover, marine environmental protection has been a top priority on the IMO's work agenda. For over two decades, the IMO has tried to ensure that developing and developed countries have access to high-quality maritime education.

In Table 6.11, the coefficients for the following variables, such as positive results, the creation of new jobs, better working conditions, and the budget to be spent on sea pollution, are evaluated in terms of education level.

**Table 6.11.** Chi-square tests and KPIs w.r.t. level of education

	<b>JHS</b>	<b>HS</b>	<b>BD</b>	<b>MSc</b>	<b>PhD</b>	<b>x<sup>2</sup></b>	<b>p-value</b>
<b>Social</b>							
Positive results	6.3%	30.6%	25%	35.9%	40%	34.417	0.023
New jobs	18.8%	38.1%	39.4%	32.15%	32%	32.754	0.036
Inform public	12.5%	1.5%	0.9%	3.8%	4%	31.902	0.044
<b>Economic</b>							
The budget for sea pollution	18.8%	41%	34.3%	41%	32%	46.806	0.05
<b>KPIs per education level</b>							
Positive results	0.53	0.76	0.72	0.77	0.74		
New jobs	0.55	0.74	0.74	0.69	0.71		
Better working conditions	0.7	0.81	0.86	0.82	0.82		
Waste management	0.23	0.37	0.38	0.34	0.5		

Citizens with a lower level of education (JHS) have rated social variables lower. Social development is directly linked to education and culture. A starting point for its effective implementation is the change in values, attitudes, mentalities, and perceptions of life, individually and collectively. However, this is a multidimensional issue. The approach requires reforms at all levels of the education system, which means changes in peoples' beliefs, stances, mentalities, and reactions to all issues. Concerning the correlation of the financial variables (e.g., budget to be spent on sea pollution) with the level of educational background, it can be concluded that the participants of the survey with a low educational experience (JHS graduates) gave a lower grading to these variables as opposed to the ones of a higher academic background. It was also noticed that there are no significant variations in the statistical analysis results among the respondents of higher education level (e.g., High school graduates to PhD holders).

### 6.6.3 Based on Factor Analysis.

For the requirements of the analysis, certain indexes had to be computed we had such as (a) the KMO index, which assesses the adequacy of the sample taken and must be at least 0.50 to proceed to factor analysis, (b) Bartlett's index, which assesses whether the relevance/correlation between variables allows the application of the factor analysis and should be significant, i.e., its p-value must

be less than 0.05 (Distefano et al., 2009) and (c) the determinant index, testing for multicollinearity and singularity of the variables and that should be greater than 0.00001 (Elmousalami, 2019). Table 6.12 illustrates these indexes for each of the three parts of the questionnaire.

**Table 6.12.** Factor analysis indexes per part

	Social	Environment	Economic
KMO	0.783	0.785	0.673
	0	0	0
Determinant	0.297	0.016	0.137

The results from factor analysis made it possible to group the variables, reducing the volume of data while retaining most of the information. Table 6.13 gives a short understanding per factor. In addition, Table 6.13 shows each variable's degree of correlation (loadings) with the (respective) factor. What can be noted is that most of the loadings are above 0.5 and, in many cases, above 0.7, which indicates a strong correlation between a variable and a factor. The variable contributes significantly to its interpretation. The research shows that the social assessment is related to two factors (Y1, Y2), the environmental with four (Y3-Y6) and the economic with three (Y7-Y9), respectively. Studying the results for each of the three areas of sustainability separately, it can be observed that social evaluation consists of two factors (Y1: Sustainable port social parameters, Y2: Public information). The first factor, Y1, consists of five variables (four of which have a load of more than 0.5), indicating the importance placed by society on shaping the port sustainability projects. The second factor (Y2) includes two variables related to environmental education and how the public is informed. As far as environmental assessment is concerned, the results have highlighted four factors (Y3: Environmental indicators assessment criteria (Pollutant), Y4: Renewable Energy Sources contribution, Y5: Pollution sources impact criteria assessment, Y6: Environmental indicators assessment criteria (traffic)). The results showed that factor Y3 consists of four variables that focus on evaluating environmental problems and, at the same time, highlight the degree of gravity for each issue. It is, therefore, stated that the citizens are highlighting air pollution, noise, and dust pollution as serious environmental problems. Factor Y4 consists of four variables that demonstrate the willingness of citizens to use specific forms of RES by indicating their preference for the use of wind and solar energy. Factor Y5 expresses citizens' views on pollution patterns and includes three variables with a similar contribution weight.

Factor Y6 involves two parameters by examining the road network. In the case of economic evaluation, the results highlighted three factors (Y7: Budget allotment criteria (Environmental

indicators), Y8: Budget allotment criteria (Traffic), and Y9: Financial involvement parties). Factor Y7 expresses the citizens' willingness to invest money to reduce the environmental impact in different sectors. The results have shown that citizens want more money to be invested in counteracting marine pollution and successful waste management. Factor Y8 describes the willingness of citizens to invest in improving the road network and consists of two variables. The results showed that both variables carry almost the same weight. Finally, factor Y9 shows the degree of participation in the road network. The results highlighted the importance of citizen participation, confirming the need to conduct our research.

**Table 6.13.** Interpretation of factors

Factor	Factor's name	Description of the factor
Y1	Sustainable port social parameters	Describes several crucial social network characteristics influencing citizen approval of a sustainable port.
Y2	Public information	Examines the importance of environmental education and public information on the benefits/risks inherent in creating a sustainable port.
Y3	Environmental indicators assessment criteria (Pollutant)	Investigates the attitudes of citizens towards environmental problems such as water pollution, air pollution, noise, etc
Y4	Renewable Energy Sources contribution	Focuses on examining and exploiting RES as one of the policies that will contribute to energy (in) dependence and tackle environmental problems. According to the citizens' opinion, various types of RES are considered to determine the most appropriate.
Y5	Pollution sources impact criteria assessment	Records citizens' attitudes towards various pollution sources to prioritize viable solutions.
Y6	Environmental indicators assessment criteria (traffic)	The current status of urban pollution resulting from transportation issues highlighted at various levels is examined (infrastructure shortages, transport system operation).
Y7	Budget allotment criteria (Environmental indicators)	Explores the relationship between environmental performance and financial performance. An attempt is made to study the extent to which investments (environmentally friendly) are necessary and where the investment should focus on having a sustainable policy.
Y8	Budget allotment criteria (Traffic)	Explores how much traffic and network quality investment is needed to improve the transportation network's efficiency (people and goods).
Y9	Financial involvement parties	Investigates the relationship between the public/private sectors and the degree of involvement in financial investment to create a sustainable port. In addition, it explores citizens' willingness to make a financial contribution to creating a sustainable port.

**Table 6.14.** Factors and loadings

<b>Social</b>	<b>Factor</b>	
	Y <sub>1</sub>	Y <sub>2</sub>
positive results	0.438	
accepted by the local	0.642	
social prosperity	0.829	
new jobs	0.753	
better working conditions	0.731	
sufficient information		0.832
seminars, info materials		-0.516

<b>Environment</b>	<b>Factor</b>			
	Y <sub>3</sub>	Y <sub>4</sub>	Y <sub>5</sub>	Y <sub>6</sub>
noise assessment	0.794			
air quality assessment	0.848			
dust assessment	0.846			
ship pollution	0.560			
road quality				0.855
traffic				0.82
civilian facilities pollution			0.786	
military facilities pollution			0.850	
ships pollution			0.785	
wind contribution		0.805		
solar contribution		0.774		
tidal contribution		0.770		
biofuels contribution		0.591		

<b>Economic</b>	<b>Factor</b>		
	Y <sub>7</sub>	Y <sub>8</sub>	Y <sub>9</sub>
air pollution	0.76		
sea pollution	0.841		
waste management	0.795		
noise	0.604		
road quality		0.889	
traffic, parking space		0.877	
Public content.			0.561
Shipping co.			0.693
civilians			0.688

## 6.7 Conclusions

As the development needs of the port continue to grow within the framework of the competition, the port facilities are called upon to address the growing challenges that arise effectively. Supporting ports' shifting functions demands a holistic perspective of ports that considers all aspects and roles, as well as port-specific demands and capabilities. Because of this diversity, the European port system is more resilient, and the optimum method for optimizing and supporting each ecosystem will be unique to each port. A local sustainability plan involves community participation (known as a bottom-up approach) to maximize the possibilities of a successful outcome. The primary reason is that only residents have a close connection to the place and the local expertise required to produce location-based solutions. Based on the above, the study's goal was to learn more about what drives ports' decisions today, how ports will adapt and navigate through this changing world, and what is needed to optimize this process so that ports in Europe can continue to be a catalyst for sustainable, innovative, and resilient growth. More specifically, it investigated citizens' level of background information and awareness on sustainable development issues, examined the degree of response/acceptance to the proposed measures for sustainable development of ports by the citizens, and identified possible problems in implementing the suggested necessary measures and proposed potential solutions.

The proposed methodology (KPI, SPSS, Factor analysis) tried to highlight any weaknesses in the operation of a major port with the broader aim of offering solutions to optimize its sustainability. The results showed that traffic and waste management have the most significant weaknesses. These weaknesses significantly degrade the environment, threatening at the same time and human health. In addition, the results showed that the infrastructure and energy sectors (e.g., RES) could significantly improve the quality of life and the environment, as significant opportunities can be turned into capabilities. Furthermore, the data analysis did not show substantial differences in the responses between men and women. The greater awareness of women explains a slight differentiation that is evident in the environmental issues compared with men. Another transparent element was the correlation of age with the environmental and economic variables. These variables are assessed lower as the respondent's age increases.

Moreover, a key measure to increase environmental concerns is to keep the citizens informed on environmental issues to ensure their participation and consider their views for future port design. Developing a comprehensive plan requires the cooperation of many different scientific disciplines. Building a framework to support interdisciplinary interactions and integrate sustainability goals into the research and development process will benefit green growth. The interactions will enable the



creation of technologies that minimize the impact on the environment, economy, and society by drawing on combined know-how in the chemical sciences, engineering, environmental health, social sciences, public policy, and business.

After analyzing and interpreting the results, specific measures were proposed to improve sustainability issues. The proposed actions can only be considered general guidelines, based on which a plan must be drawn up after analyzing the current situation.

This methodology aims to support government policymakers and regulators in implementing reforms to build a sustainable port system. This survey aimed to contribute solutions and proposals to the maritime industry to align the objectives of the European Green Agreement and the SDGs.

The impact of this study in the case of other ports is multi-faceted. Firstly, this study presents vital concepts such as creating a green, sustainable port. Moreover, the methodology proposed reveals the involvement of citizens in finding problems and solutions for any ports. In practice, our study provides a comprehensive assessment of various sustainability criteria of port facilities to achieve sustainable development goals. The research findings point to any overlooked improvements and require more collective effort. The proposed methodology also serves as a self-assessment tool for an individual port facility about its current stage of sustainable development. It creates implications for future SBG implementation strategies. With the support and guidance of our research and a collaborative approach between ports and city authorities, there is a great window of opportunity to make improvements that will benefit ports, local communities, and the environment.

Future research may focus exclusively on port and policy managers' views. The study focused on specific groups of citizens, which gives extra weight due to their expertise and experience. Further future research may explore any incentives, funding, and technology development. In addition, the effectiveness of the proposed measures to reshape the attitude of respondents should be considered in a future research effort.

Some limitations to our methodology are essential to acknowledge. The present survey was conducted in the winter of 2019, noting the absence of responses from tourists who have different criteria from local passengers (permanent residents) of other periods. The research results cannot be generalized as they examined only a specific period. Another limitation of our study is the higher percentage of men's responses than women's. The lower percentage of women's responses is because the work in port infrastructure is done mainly by men and not because of gender bias, as our research specifically studied women's answers. Women must be involved in designing and implementing sustainable solutions because their perspectives can help create realistic, user-friendly infrastructure and services.

## **Chapter 7-Assessing Sustainable Indicators in Small/ Medium Ports**

## 1.1 Introduction

More than 90 percent of international trade occurs on the world's oceans, making the maritime sector crucial to the world's economy (Balcombe et al., 2019). Within this framework, the widely recognized significance of ports in the global sustainability challenge is acknowledged, and numerous global initiatives have been implemented to evaluate the sustainability of port facilities (Xue & Lai, 2023). Ports are constantly expanding, increasing, and modernizing to meet global trade needs and contribute significantly to various activities focusing on financial, environmental, and technological sectors (López-Bermúdez et al., 2020). As crucial links in the worldwide supply chain, ports have a unique opportunity to spearhead sustainable practices. While larger ports often grab the headlines, small/medium-sized ports (SMSPs) quietly make significant strides toward sustainability.

For many reasons, the necessity to give precedence to sustainability has assumed paramount importance for SMSPs in the 21st century. First and foremost, sustainability follows the worldwide imperative to address climate change and mitigate environmental consequences. SMSPs have the potential to substantially diminish their environmental impact by incorporating environmentally friendly measures, such as the electrification of equipment, utilization of renewable energy sources, and adoption of smart devices. Furthermore, with the growing emphasis on sustainability among consumers and businesses, SMSPs that stress environmental friendliness are more likely to appeal to shipping companies and cargo owners seeking to minimize carbon emissions. SMSPs that adopt sustainable practices enhance their prospects for expansion as they become more attractive to prospective collaborators, investors, and sources of money, thereby reinforcing their significance in local and national economies. Fundamentally, improving the sustainability of SMSPs is a strategic necessity that can yield advantages in terms of the environment, economy, and operations.

In the contemporary era, as sustainability becomes increasingly pivotal in the global maritime sector, it is essential to understand and set a standard for evaluating these ports' environmental, financial, and societal effectiveness (Hossain et al., 2021). Port sustainability encompasses various dimensions and may be adequately assessed and quantified using diverse essential indicators (Othman et al., 2022). Incorporating sustainability indicators into port management procedures is imperative to promote a more environmentally conscious, socially accountable, and economically sustainable future for these crucial global trade and commerce centers (Kong & Liu, 2021). By systematically monitoring and evaluating indicators, ports can assess their sustainability initiatives and pinpoint areas that require enhancement (Schipper et al., 2017). This enables them to make well-informed decisions to improve their overall sustainability performance.

While past studies have tried to compare sustainable indicators at ports, significant scientific gaps still warrant further investigation. One prominent research gap in comparing sustainable indicators at different ports is the limited number of comparative studies across various ports worldwide. While numerous studies focus on practices at individual ports, there is a need for more research that directly compares sustainability performance among different ports. Such comparative studies are vital for identifying best practices, benchmarking performance, and facilitating knowledge sharing and collaboration between ports. Moreover, ports vary significantly in size, capacity, and operational activities. However, research gaps exist in adequately considering the influence of port size and type on the selection and performance of sustainable indicators. Larger ports with extensive infrastructure and operations may have different sustainability challenges than smaller ports with limited resources. This article seeks to tackle the identified research gaps by exploring the following questions:

What core sustainability indicators benchmark SMSPs' performance regarding environmental, social, and economic sustainability, and how do these indicators vary across different regions and port sizes?

The novelty of this research lies in its comprehensive methodology for evaluating sustainable indicators in SMSPs, encompassing the environmental, economic, and social aspects of sustainability. Furthermore, the originality of this research resides in promoting the exchange of knowledge and facilitating collaboration within the context of SMSPs. Traditionally, these ports have functioned with limited avenues for exchanging obstacles and achievements. Nevertheless, this study significantly contributes by developing a mechanism to share best practices and lessons learned among these ports.

Multiple-criteria decision analysis (MCDM) techniques are used to compare indicators in this research. According to the literature, these are valuable techniques for solving sustainability issues containing uncertainty and have been widely adopted by researchers and experts in various disciplines (Nasrollahi et al., 2023; Wei et al., 2021). They have been used in research such as technological innovation (Laguna Salvadó et al., 2022; Nikas et al., 2018), quality of life (Ramirez-Ibarra & Saphores, 2023; Vakili-pour et al., 2021), consumer beliefs (Broniewicz & Ogrodnik, 2021), water resources management (Garai & Garg, 2022), and port/cities sustainability (Rehman et al., 2022).

Our research has looked deeper into the indicators for assessing the sustainable performance of ports using a combination of the BWM and VIKOR methods. BWM provides a comprehensive analysis by allowing decision-makers to determine the best and worst indicators among alternatives (Rezaei et al., 2018). By considering the best and worst indicators, the BWM method captures each

alternative's possibilities and potential risks, leading to more robust and informed decision-making. In addition, the VIKOR methodology provides a systematic approach to evaluating alternatives and finding the most satisfactory compromise. VIKOR is preferable to port sustainability problem-solving methods due to its simplicity, robustness, and ability to handle multiple criteria and trade-offs. In comparison, methods like the Analytic Hierarchy Process (AHP) or Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) may involve more intricate calculations. In the content of this research, four different ports located in Crete (Greece) are studied as case studies. The regional focus on Crete underlines the Mediterranean's intricate balance between environmental conservation, cultural heritage preservation, and economic development in port sustainability. However, globally, variations in sustainability priorities among ports emerge due to diverse geographical conditions, economic activities, and regulatory frameworks, influencing their emphasis on environmental impact mitigation, community engagement, and industry-specific sustainability measures.

The subsequent sections of the paper are organized as follows: The second part is dedicated to conducting a comprehensive literature review. The text examines sustainable development, which forms the foundation for environmental indicators. It also analyses the critical indicators of sustainable port development. The third section pertains to the methodology. The fourth part displays the survey findings, while section six examines the research outcomes. The fifth part presents the discussions, and the last describes the conclusions.

## **1.2 Literature review**

Sustainable port operating procedures have been studied through research in several ways (Oh et al., 2018). However, due to the interconnectedness of numerous internal and external factors, it isn't easy to define specific evaluation indicators (Lim et al., 2019). To account for this nuance, researchers have created a diverse set of quantitative indicators to assess sustainability performance within the context of ports. (Roos & Kliemann Neto, 2017) various tools and evaluation methods have been used to assign relative importance to each indicator, such as Environmental Management Systems (Chlomoudis et al., 2024), Eco-Management and Audit Scheme (Tatar, n.d.), and Port Environmental Review System.

Relevant literature has identified various methodologies to enhance the sustainability of ports by increasing competitiveness and customer service (Tovar et al., 2015; Yang et al., 2022). (Puig et al., 2014, 2017) established a method for measuring port authorities' progress toward environmental sustainability using various indicators. These indicators are utilized in 19 ports in Norway and

Iceland (Peoples et al., 2022). Furthermore, (Puig et al., 2020) employed the self-diagnosis technique, enabling ports to evaluate their environmental management. The outcomes provided insights into various environmental management metrics, with environmental policy securing the highest percentage (96.7%) and environmental legislation taking the second position with a rate of (95.7%). (Faut et al., 2023) created a complete collection of workable Circular Economy (CE) indicators for ports. The research offers a practical set of KPIs to aid the CE transition's associated activities and communication.

In recent decades, the United Nations (UN) has promoted sustainable development by shaping the conditions for dialogue among member states and new field policies. The UN Sustainable Development Goals (SDGs)" is a framework that aims to improve the quality of life, protect the environment, and reduce inequality by 2030 (Caliskan, 2022). The SDGs represent a collective vision for a better world based on the definition of sustainable development (Fonseca & Carvalho, 2019). Furthermore, the SDGs set priorities and define the guiding goal for global development and sustainable transition. On the other hand, sustainable indicators are the means to measure and assess progress toward these goals. In this context, the indicators provide the tools to monitor progress and identify areas requiring further efforts. The United Nations' Sustainable Development Goals (SDGs) significantly influence the global maritime sector, particularly SDG 14, which focuses on Life Below Water, and SDG 9, which focuses on Industry, Innovation, and Infrastructure. These goals drive the maritime industry to address marine conservation, reduce pollution, and invest in sustainable infrastructure and innovation. Beyond the SDGs, international frameworks like the International Maritime Organization (IMO) regulations, the World Ports Sustainability Program (WPSP), and initiatives tied to the Paris Agreement shape sustainability efforts in ports globally. These frameworks guide ports in emissions reduction, safety standards, and collaborative sustainability initiatives, aligning the sector with environmental stewardship, social responsibility, and economic resilience goals.

### **7.3 Sustainable indicators**

In advancing the sustainability of ports, indicators for sustainability have been formulated and applied to gauge, observe, and enhance the environmental, economic, and social performance of ports in the following manner:

#### **7.3.1. Environmental sustainability/indicators**

The first environmental indicators in ports emerged decades ago and addressed environmental challenges like water pollution. Nevertheless, due to the progress made in scientific research and the emergence of a worldwide consciousness regarding sustainability, environmental indicators

have transformed to encompass more intricate elements, such as safeguarding biodiversity, effectively managing trash, and using renewable energy sources (Rodrigues et al., 2021). Numerous emerging trends and innovations have been observed globally, showcasing a commitment to environmental sustainability. Some key trends and notable initiatives from different regions are described as follows: The Port of Los Angeles & Long Beach (USA) have invested in zero-emission equipment and infrastructure. Initiatives include the Clean Trucks Program, the Clean Air Action Plan, and the development of hydrogen fuel cell trucks and electric cargo-handling equipment. Port of Vancouver (Canada) has implemented shore power facilities to enable ships to plug into electrical power at berth, reducing the need to run their engines and cutting emissions significantly. The Port of Singapore utilizes innovative technologies for efficient traffic management, which reduces vessel waiting times, optimizes routes, and minimizes fuel consumption and emissions. These examples illustrate a global shift towards environmentally sustainable practices in ports, encompassing various strategies and technologies to reduce emissions, conserve natural resources, and promote a greener future for maritime operations.

### **7.3.2. Economic sustainability/indicators**

Ports play a crucial role in fostering economic expansion and worldwide connectivity, functioning as essential entry points that enable the flow of goods, resources, and ideas across national borders. The economic contribution of ports extends far beyond their immediate vicinity, as they form integral components of supply chains, supporting industries, and trade networks on a regional and international scale (K. Chen et al., 2023). Some examples are the Port of Shanghai (China), the Port of Los Angeles (USA), and the Port of Rotterdam (Netherlands). Ports are essential to global trade and contribute significantly to their countries' economies. Over time, these indicators have evolved to include complex aspects such as port competitiveness, investment growth, job creation, and the contribution of ports to the national economy.

### **7.3.3. Social sustainability/indicators**

Ports are essential in stimulating economic progress and providing significant social benefits to the communities within their operational areas. Beyond the bustling terminals and cargo handling, ports serve as hubs of social interaction and engagement, fostering community development and offering various opportunities for social advancement. The Port of Antwerp in Belgium collaborates with stakeholders to ensure that goods passing through its terminals adhere to ethical standards, fostering responsible trade practices and supporting socially sustainable supply chains. The Port of Barcelona

in Spain promotes sustainable mobility by supporting public transportation projects, reducing traffic congestion, and enhancing connectivity for residents living near the port area.

#### **7.4 Main indicators**

The main and sub-indicators for sustainability are chosen through stakeholder engagement, literature review, and consideration of international standards. Elsevier and Google Scholar were used to conduct a literature search at this stage. Elsevier was chosen as a source for the literature search for articles, whereas Google Scholar was utilized for the literature search for dissertations and other material forms. The words used include "indicators," "Small /Medium Ports," and "Sustainability". For the research, the following main sustainability indicators were used:

##### **7.4.1. Green Infrastructure (GI)**

Green infrastructure has gained prominence as a sustainable approach to address environmental challenges in various sectors, and its application in ports has garnered increasing attention (Twrdy & Zanne, 2020). Embracing green infrastructure practices allows ports to improve environmental performance and foster sustainable development. This article compares green infrastructure initiatives at different ports, highlighting their approaches, successes, and challenges while identifying key points that can enhance the understanding and implementation of green infrastructure in the port sector.

##### **7.4.2 Environmental Monitoring and Management (EMM)**

Monitoring can prove helpful in ensuring that port policy is pursued and assessing each management choice's efficacy (Cammin et al., 2020). Monitoring is the systematic and repetitive measurement, among others, of the direct or indirect effects of our activity or contaminant on the ecosystem (Puig et al., 2022). An effective monitoring strategy makes it easier to address issues like adherence to particular regulatory standards, examination of pollution patterns, provision of research data, measurements for establishing standards, and early notification of involved actors on essential changes in specific project parameters (Negulescu et al., 2022).

##### **7.4.3 Management of energy (ME)**

Examining energy management practices across diverse ports offers valuable insights into the range of approaches and the effectiveness of different strategies. By examining case studies from other regions and port typologies, it explores the adoption of renewable energy technologies, energy efficiency measures, and innovative practices that ports employ to optimize their energy use. This



comparative analysis enables port authorities, policymakers, and stakeholders to learn from successful experiences, identify transferable solutions, and foster the uptake of sustainable practices in the port infrastructure.

#### **7.4.4 Technology (TE)**

Technology has transformed port operations into efficient, interconnected global trade centers. Container tracking and management systems are examples of automated systems that have streamlined processes, reduced human error, and increased overall productivity (Min, 2022). Advanced data analytics allows ports to optimize operations by analyzing real-time vessel schedules, cargo volumes, and logistics information (W. Chen et al., 2023). Employing a data-driven approach enhances decision-making, empowering port authorities to allocate resources effectively, alleviate congestion, and improve overall efficiency.

#### **7.4.5 Approaches for Waste Management and Recycling (WM&R)**

The effective management of waste and implementation of recycling strategies are critical components of sustainability in the maritime sector. As key gateways for international trade and transport, ports significantly minimize waste generation, reduce environmental impacts, and promote the circular economy. Implementing efficient waste management and recycling strategies at ports can conserve resources, reduce pollution, and enhance environmental stewardship. This article aims to compare waste management and recycling strategies at different ports, examining their approaches, achievements, and challenges while further identifying research gaps to enhance sustainable maritime industry waste practices.

#### **7.4.6 Training of employees in environmentally responsible practices (EET)**

The competence and skills of port employees are crucial for ensuring safe, efficient, and sustainable operations in the maritime sector. Analyzing training practices among various ports provides valuable insights into the range of approaches and the effectiveness of different training programs. By examining case studies from different regions and port sizes, we can explore the adoption of training methodologies, certification programs, and innovative approaches employed by ports to enhance the competence and performance of their employees.

#### **7.4.7 Security of Employment and Social Protection (SE&SP)**

Ensuring employment security and providing adequate social protection for workers are fundamental aspects of creating a sustainable and inclusive maritime sector. Numerous regulations, guidelines, and best practices have been established to improve port safety and security (Nebot et al., 2017). The International Maritime Organization's statutory requirements, which include those listed below, are among the most significant. a) the Convention for Safety of Life at Sea , b) the Seafarers' Training, Certification and Watch-keeping Code (Choi et al., 2022), and c) the International Safety Management. Through adequate employment security and social protection measures, ports can ensure the welfare of their workforce, enhance productivity, and contribute to a fair and inclusive port industry.

#### **7.4.8 Competitiveness (CMS)**

In the contemporary globalized economy, ports are key facilitators of international trade and commerce. To thrive in this highly competitive landscape, ports worldwide have implemented diverse strategies to enhance their competitiveness and maintain a leading position in the market. The comparative analysis explores different ports' competitive strategies and assesses their effectiveness in achieving growth, efficiency, and customer satisfaction. Studying the approaches these ports adopt provides valuable insights into the elements contributing to their success, allowing for the identification of best practices in port management.

**Table 7.1.** Main and sub-indicators to evaluate the ports' sustainable performance.

Main indicators	Sub-indicators	Code	Description	Authors
GI	a. Green infrastructure design b. Energy-saving strategies c. Eco-friendly parking space at the port d. Solar energy storage capacity facilities e. Functional and aesthetic infrastructure planning	GI 1 GI 2 GI 3 GI 4 GI 5	Climate and the environment are less negatively impacted by its design, construction, or operation, and positive effects may also result from these factors.	(Biyik et al., 2021; Sdoukopoulos et al., 2019; Vichos et al., 2022; Xiang et al., 2022)
EMM	a. Environmental and energy management certification b. Mitigating the emission of greenhouse gases c. Inventory database for greenhouse gas (GHG) emissions d. Recommendations for the framework for a clean development project e. Implementation of policies and regulations for green areas	EMM 1 EMM 2 EMM 3 EMM 4 EMM 5	Policymakers, international organizations, and the general public can be informed on environmental trends and conditions and promote policy development with environmental monitoring.	(Alamouh et al., 2022b; Sun and Zhao, 2023)
ME	a. Energy control equipment system for lighting, heating, etc. b. Energy management plan c. Replace old-fashioned equipment with greener technology d. Use of RES e. Monitoring system of energy consumption	ME 1 ME 2 ME 3 ME 4 ME 5	Energy management is the proactive, planned, and systematic coordination of energy production, delivery, and consumption to satisfy demand while considering environmental and financial goals.	(Acciaro et al., 2014c; Bjerkan and Seter, 2019d; Sifakis and Tsoutsos, 2021d)
TE	a. Cyber security measures b. Green Technology c. Automated systems d. Real-time systems e. Smart technology	TE 1 TE 2 TE 3 TE 4 TE 5	Technology is revolutionizing the port world, altering how goods are handled and enhancing overall efficiency and security. Technological advancements in recent years have reshaped the port industry, significantly improving operations, logistics, and safety measures.	(Belmoukari et al., 2023; Ding et al., 2023)

WM&R	a. Use of online tools for monitoring waste b. Increase awareness of waste management among stakeholders c. Financial incentives for stakeholders d. Penalty paid due to illegal dumping of waste e. Waste prevention plan	WM&R 1 WM&R 2 WM&R 3 WM&R 4 WM&R 5	Waste management aims to promote waste treatment alternatives that are appropriate for the waste, particularly favoring reuse and recycling.	(Al-Hakimi et al., 2022; Clayton et al., 2021; Martínez-López et al., 2020; Mikulčić et al., 2022)
EET	a. Education seminars for energy conservation b. Cooperation with other ports for lessons learned c. Collaboration with the appropriate organization d. Participation in projects to increase sustainability e. Incentives (financial and social, professional) for their involvement in educational programs	EET 1 EET 2 EET 3 EET 4 EET 5	Green training and development provide staff with practices that guarantee adequate resource utilization, decrease waste, promote energy conservation, and minimize the causes of environmental degradation.	(Amrutha and Geetha, 2021; Luo et al., 2022)
SE&SP	a. Security plan b. Safety Plan c. Adopt measures and create appropriate infrastructure for the safety of ships from external factors (e.g., weather conditions, etc.) d. Staff training on security and safety issues e. Cooperation with other bodies for the exchange of information on security issues	SE&SP 1 SE&SP 2 SE&SP 3 SE&SP 4 SE&SP 5	This sector at ports aims to equip governments, enterprises, employees, and other stakeholders with the resources they need to reduce the threat posed by illicit activities.	(Aneziris et al., 2020; Sas et al., 2019)
CMS	a. Economy b. Employment c. Tourism d. Research and development e. Technology	CMS 1 CMS 2 CMS 3 CMS 4 CMS 5	Competitiveness refers to a port's ability to attract customers by providing superior goods, services, and other amenities.	(Bottasso et al., 2013; Gómez-Vega & J Picazo-Tadeo, 2019; Wu et al., 2022)

## **7.5 Case studies/Identification of experts**

The next step was identifying experts and studying ports and case studies. Four different SMSPs were examined for the research needs. They are situated in Crete, the fifth-biggest island in the Mediterranean and one of the most populous Greek islands. The four ports were chosen in this context to compare their efficacy in terms of sustainability and to collect data to assist port operators in future port design decisions. Fig. 1 includes yearly data for each port, giving a broad picture of their operations. Respective Coast Guard authorities provided the data. Concerning the identification of experts, five experts from each port with more than ten years of experience in port facilities and various agencies (Port Authorities, Harbour Management Organisations, Academics, Nearby Municipalities, and Port Security Officers) participated in the survey. The data collection process lasted roughly four months (December 2022 to March 2023).

### **a. Port of Souda, Chania (CHA)**

CHA, positioned as one of the largest and secure ports in the Mediterranean, serves various purposes, including passenger transportation, tourism, water sports, and fishing. Benefiting substantially from its strategic location at the intersection of major maritime routes, Chania has experienced notable commercial, tourism, and economic growth in recent decades. Notably, it has emerged as a critical destination for cruise ships, further enhancing its significance. The port's strategic importance is underscored by its hosting of naval military infrastructures (Argyriou et al., 2022).

### **b. Port of Heraklion (HER)**

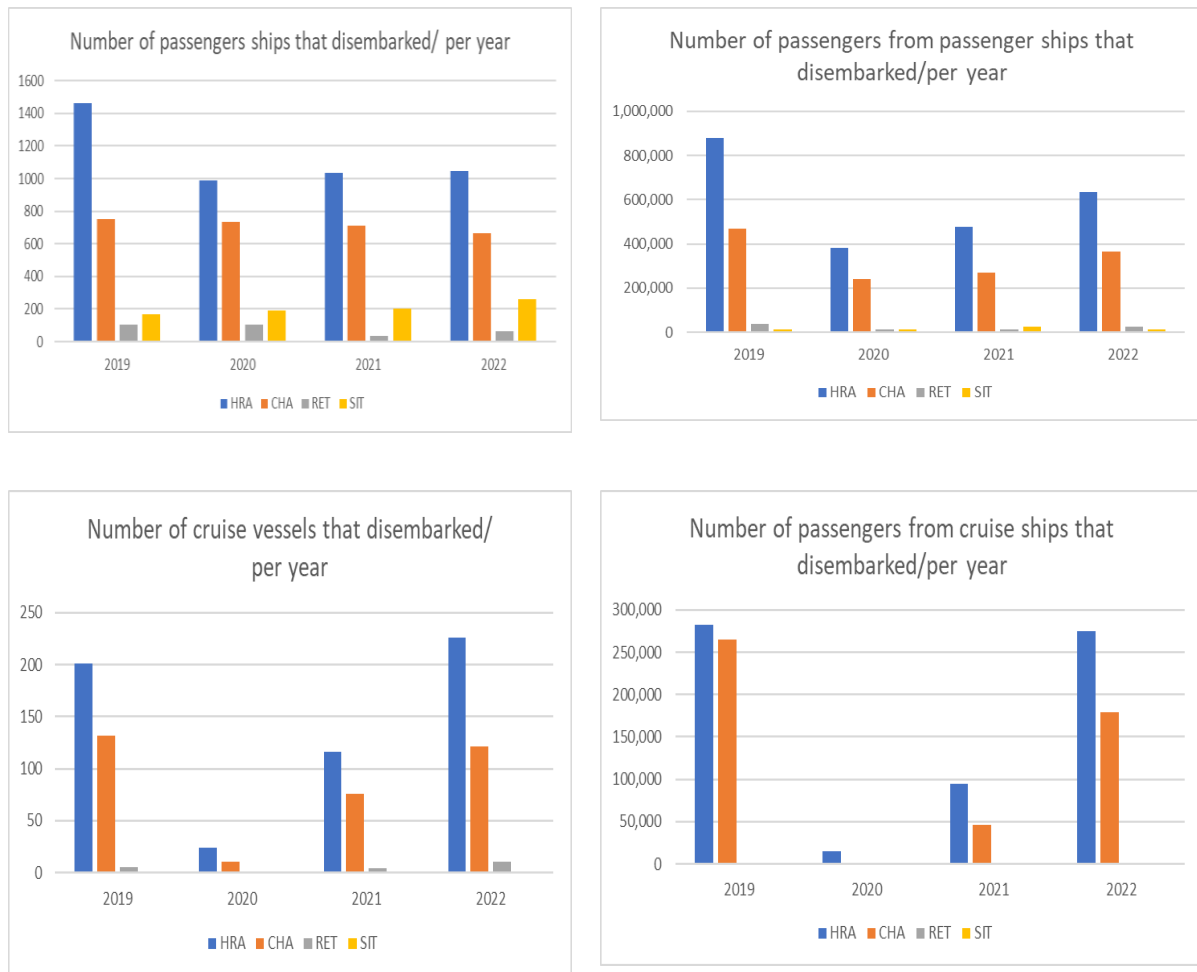
HER is a key passenger and freight hub in the Mediterranean basin. Passenger and commercial ships visit the port with frequent itineraries throughout the year. HER has become one of the main cruise ship destinations in the Mediterranean (Chatzinikolaou & Arvanitidis, 2016).

### **c. Port of Rethymnon (RET)**

RET is the third-largest city of Crete, located between Chania and Heraklion. Its ferry connections with other areas vary, so a connection should not be taken for granted yearly. The ferry is also used to transport goods, while several tourist boats offer day cruises in the summer.

### **d. Port of Sitia (SIT)**

SIT is the port of the easternmost prefecture of Crete and an ideal holiday destination, as it combines some of the most beautiful elements of Crete. There is a ferry connection with other areas, but it is less frequent than other ports of Crete.



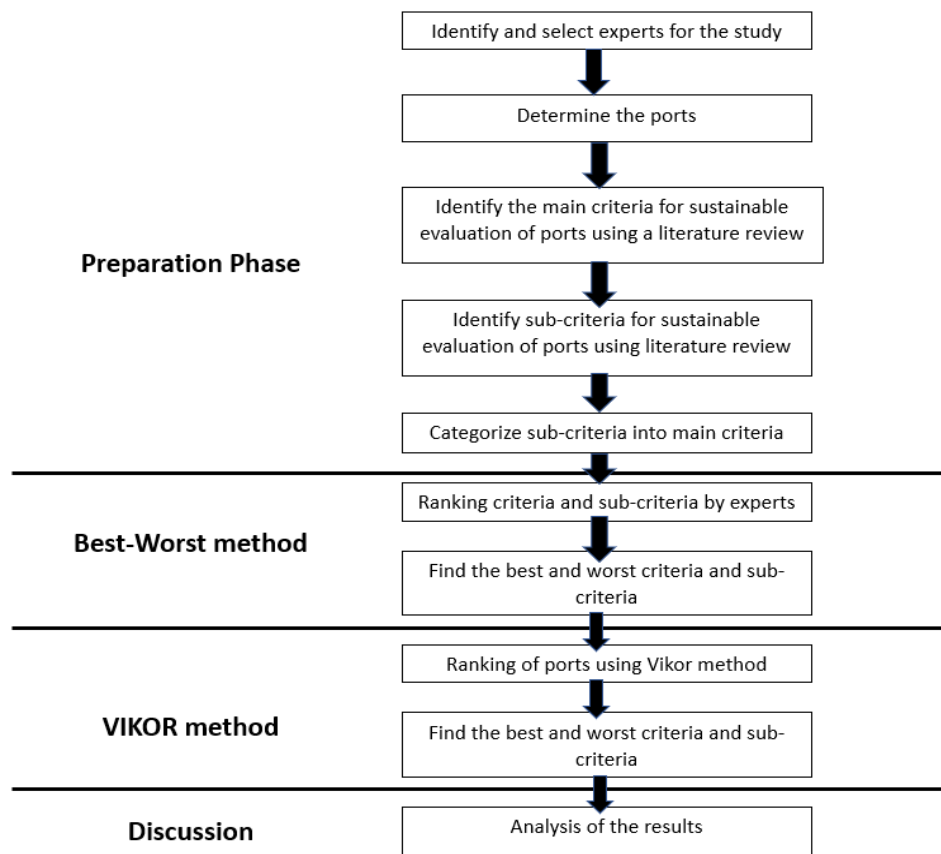
**Figure 7.1.** Statistical data: a. Number of passenger ships that disembarked, b) Number of passengers from passenger ships that disembarked, c) Number of cruise vessels that disembarked, and d) Number of passengers from cruise ships that disembarked.

From the analysis above, the port with the most significant activity is the HER. The second most visited is the CHA, followed by the SIT and RET. For this research, HRA and CHA are characterized as medium ports, while RET and SIT are small ports.

## 7.6 Description of survey phases

The research was developed in different phases to assess the ports' sustainability indicators and compare them (Fig. 2). The first was the identification of research gaps. As discussed in the previous section, the key points of this research are identifying best practices in sustainable development and the benefits of sharing knowledge and lessons learned. The next step was to identify experts and study ports. Five experts from each port with more than ten years of experience in port facilities and various agencies (Port Authorities, Harbour Management Organisations, Academics, Nearby

Municipalities, and Port Security Officers) participated in the survey. The following step was to identify the main and sub-indicators. The primary and sub-indicators for sustainability are chosen through stakeholder engagement, literature review, and consideration of international standards. Elsevier and Google Scholar were used to conduct a literature search at this stage. Elsevier was chosen as a source for the literature search for articles, whereas Google Scholar was utilized for the literature search for dissertations and other material forms. The words used include "indicators," "Small/Medium Ports," and "Sustainability." The experts were instructed to rank the indicators from most vital to least vital. The evaluation of indicators was applied to different methods, such as BMW and VIKOR. By using the BWM, a calibration of the primary and sub-indicators was done. Subsequently, the sustainability of the examined ports was evaluated using the VIKOR methodology, focusing on the selected indicators. The data collection process lasted roughly four months (December 2022 to March 2023).



**Figure 7.2.** Stages of the recommended method

## 7.7 Methodology

### 7.7.1 Best worst method (BWM)

Following is a description of the steps as provided by (Rezaei, 2016, 2015)

**Step 1:** Choosing the attributes to be analyzed after reviewing the literature and consulting experts.

**Step 2:** The experts were asked to rate all indicators and select the best and worst of every category.

**Step 3:** The experts were requested to categorize the selected attributes based on step 2, using the worst attribute as the initial reference point.

**Step 4:** The optimum weights ( $w_1^*, w_2^*, \dots, w_n^*$ ) were determined for each attribute. The study aims to establish attribute weights so that the greatest absolute differences for each  $j$  may be reduced to the smallest possible value for  $\{|w_B - \alpha_{Bj}w_j|, |w_j - \alpha_{jWW}|\}$ . The subsequent model will be acquired:

$$\min \max \{|w_B - \alpha_{Bj}w_j|, |w_j - \alpha_{jWW}|\}$$

$$\text{s.t. } \sum_{ij} w_j = 1$$

$$w_j \geq 0 \text{ for all } j \quad (1)$$

Model (1) is presented below and then changed into a linear model, which gives results in a more demonstrative way:

$$\min \xi^L$$

$$\text{s.t.}$$

$$|w_B - \alpha_{Bj}w_j| \leq \xi^L, \text{ for all } j$$

$$|w_j - \alpha_{jWW}| \leq \xi^L, \text{ for all } j$$

$$\sum_j w_j = 1$$

$$w_j \geq 0 \text{ for all } j \quad (2)$$

Model (2) can be solved to provide the best weights ( $w_1^*, w_2^*, \dots, w_n^*$ ) and the best value for  $\xi^L$ .

Attribute comparisons ( $\xi^L$ ) are preferred to be consistently close to 0 (Rezaei, 2016).



### 7.7.2 Vikor analysis

The following steps depict the VIKOR approach (Hezer et al., 2021; Liang et al., 2021).

**Step 1:** Using the magnitude presented in Table 2, a matrix of indicators and options needed to be created.

**Table 7.1.** Scale for comparison matrix according to the VIKOR methodology.

Vikor technique scale	
Significant scale	Grade
Extremely significant	1
Very strong significant	2
Strongly significant	3
Significant	4
Low significant	5

**Step 2:** The average decision matrix was discovered using equation (3).

$$F = \frac{1}{k} \sum_{k=1}^k F_k \quad (3)$$

where F represents the typical matrix, and k represents the number of experts.

**Step 3:** Equations (4) and (5) are used to determine the best  $f_b^*$  and worst  $f_b^-$  values for all the indicators,  $b = 1, 2, n$

$$f_b^* = \text{Max}(f_{ab}) \quad (4)$$

$$f_b^- = \text{Min}(f_{ab}) \quad (5)$$

where  $f_b^*$  is the optimal solution's positive and  $f_b^-$  negative values for both attributes, respectively.

**Step 4:**  $S_a$  and  $R_a$  values should be calculated for  $a = 1, 2, \dots, n$  utilizing equations (6) and (7).

$$S_a = \sum_{b=1}^n W_b [(f_b^* - f_{ab}^{\square}) / (f_b^* - f_b^-)] \quad (6)$$

$$R_a = \text{Max}_b \left[ \frac{W_b (f_b^* - f_{ab}^{\square})}{f_b^* - f_b^-} \right] \quad (7)$$

The solutions offered by  $S_a$  and  $R_a$  are based on the indicators of the opponent's last individual regret and the most significant group utility, respectively.  $W_b$  denotes the weights of the indicators.

**Step 5:** To calculate the scores for  $Q_a$ , equation (8) was used.

$$Q_a = v \left( \frac{S_a - S^*}{S^- - S^*} \right) + (1 - v) \left( \frac{R_a - R^*}{R^- - R^*} \right) \quad (8)$$

$S^- = \text{Max}_a S_a$ ,  $S^* = \text{Min}_a S_a$ ,  $R^- = \text{Max}_a R_a$ ,  $R^* = \text{Min}_a R_a$ , where  $v$  gives the weight of the strategy of "the majority of indicators" (or the most extensive group utility); in this case,  $v = 0.5$ . Within a decision-making procedure, such as "vote by majority rule" (when  $v > 0.5$  is required), "by consensus" (when  $v = 0.5$ ), or "with veto" (when  $v < 0.5$ ).  $Q_a$  indicates the VIKOR index.

**Step 6:** The alternatives were ranked using  $Q_a$  values.

**Step 7:** The alternatives were ranked according to the minimum  $Q_a$  values derived by concurrently fulfilling two conditions:

**Condition 1.**  $Q(A(1))$  is chosen if  $Q(A(2)) - Q(A(1)) \geq 1/n-1$ , where  $A(2)$  is the alternative that came second in the analysis, and  $n$  represents the total alternatives.

**Condition 2.** According to both  $S_a$  and  $R_a$  values,  $Q(A(1))$  achieves the first rank.

**Step 8:** As an alternative, the minimum score in  $Q_a$  achieved is ranked first.

## 7.8 Results

### 7.8.1 Best Worst Method

The BWM was utilized to identify which indicators for HER are best and which are not. After receiving all ratings, the weights for each criterion were calculated using equation (2). The best and worst indicators for HER, defined by various experts, are shown in Table 3. After solving equation (4) and averaging the calculated values, the aggregated weights are depicted in Table 4. The annex contains the outcomes for the remaining ports (CHA-RET-SIT). In addition, Table 5 displays the results for each port and criterion, considering all expert responses.

**Table 7.3.** Total number of experts who selected specific indicators as best and worst, respectively, at HER.

Main indicators	Selected as the best sub-indicator by experts	Chosen as the worst sub-indicator by experts
<b>GI</b>		
GI 1		1
GI 2		3
GI 3		1
GI 4		
GI 5	5	
<b>EMM</b>		
EMM1		2
EMM2		
EMM3		3
EMM4		
EMM5	5	
<b>ME</b>		
ME 1		
ME 2	5	
ME 3		
ME 4		
ME 5		5
<b>TE</b>		
TE 1		2
TE 2		
TE 3		
TE 4		3
TE 5	5	

<b>WM&amp;R</b>		
WM&R 1		3
WM&R 2		1
WM&R 3		
WM&R 4		1
WM&R 5	5	
<b>EET</b>		
EET 1	3	
EET 2		
EET 3		
EET 4		5
EET 5	2	
<b>SE&amp;SP</b>		
SE&SP 1		
SE&SP 2		
SE&SP 3		
SE&SP 4		5
SE&SP 5	5	
<b>CMS</b>		
CMS 1	2	
CMS 2	1	
CMS 3	2	
CMS 4		3
CMS 5		2

**Table 7.4.** Aggregate weights of main and sub-indicators for all experts (HRA-port)

Main Indicators	Weights of Main Indicators	Sub Indicators	Weights of Sub-Indicators	Global Weights	Ranking
GI	0.033	GI 1	0.356	0.004	39
		GI 2	0.189	0.007	33
		GI 3	0.081	0.003	40
		GI 4	0.158	0.005	38
		GI 5	0.217	0.014	25
EMM	0.331	EMM 1	0.172	0.037	9
		EMM 2	0.133	0.05	5
		EMM 3	0.16	0.032	10
		EMM 4	0.38	0.136	1
		EMM 5	0.165	0.076	3
ME	0.1	ME 1	0.134	0.019	19
		ME 2	0.416	0.041	6
		ME 3	0.188	0.017	20
		ME 4	0.158	0.015	23
		ME 5	0.106	0.008	32
TE	0.133	TE 1	0.168	0.014	24
		TE 2	0.275	0.025	13
		TE 3	0.174	0.027	12
		TE 4	0.098	0.013	27
		TE 5	0.284	0.054	4
WM&R	0.056	WM&R 1	0.203	0.006	37
		WM&R 2	0.208	0.008	31
		WM&R 3	0.126	0.011	28
		WM&R 4	0.114	0.008	30
		WM&R 5	0.347	0.023	15
EET	0.08	EET 1	0.185	0.027	11
		EET 2	0.201	0.014	26
		EET 3	0.131	0.01	29
		EET 4	0.241	0.006	36
		EET 5	0.242	0.023	16
SE&SP	0.2	SE&SP 1	0.344	0.038	8
		SE&SP 2	0.256	0.024	14
		SE&SP 3	0.209	0.016	21
		SE&SP 4	0.118	0.082	2
		SE&SP 5	0.072	0.04	7
CMS	0.067	CMS 1	0.328	0.019	18
		CMS 2	0.165	0.015	22
		CMS 3	0.108	0.02	17
		CMS 4	0.269	0.06	35
		CMS 5	0.131	0.007	34

**Table 7.5.** Results for each port and each sub-indicator, considering all expert responses

	GI 1	GI 2	GI 3	GI 4	GI 5	EMM 1	EMM 2	EMM 3	EMM 4	EMM 5	ME 1	ME 2	ME 3	ME 4	ME 5	TE 1	TE 2	TE 3	TE 4	TE 5
HRA	0.004	0.007	0.003	0.005	0.014	0.037	0.05	0.032	0.136	0.076	0.019	0.041	0.017	0.015	0.008	0.014	0.025	0.027	0.013	0.054
CHA	0.004	0.01	0.004	0.005	0.01	0.026	0.052	0.045	0.136	0.072	0.019	0.041	0.018	0.011	0.011	0.009	0.014	0.012	0.005	0.027
RET	0.009	0.011	0.003	0.004	0.006	0.048	0.028	0.016	0.075	0.033	0.012	0.027	0.012	0.005	0.011	0.011	0.025	0.029	0.011	0.024
SIT	0.011	0.008	0.003	0.005	0.006	0.046	0.024	0.022	0.082	0.026	0.011	0.023	0.009	0.005	0.019	0.011	0.025	0.027	0.01	0.027
$f_b^*$	0.004	0.011	0.004	0.005	0.014	0.048	0.052	0.045	0.136	0.076	0.019	0.041	0.018	0.015	0.019	0.014	0.025	0.029	0.013	0.054
$f_b^-$	0.004	0.007	0.003	0.004	0.006	0.026	0.024	0.016	0.075	0.026	0.011	0.023	0.009	0.005	0.008	0.009	0.014	0.012	0.005	0.024

	WM & R 1	WM & R 2	WM & R 3	WM & R 4	WM & R 5	SE&SP 1	SE&SP 2	SE&SP 3	SE&SP 4	SE&SP 5	EET 1	EET 2	EET 3	EET 4	EET 5	CMS 1	CMS 2	CMS 3	CMS 4	CMS 5
HRA	0.006	0.008	0.011	0.008	0.023	0.027	0.014	0.01	0.006	0.023	0.038	0.024	0.016	0.082	0.04	0.019	0.015	0.02	0.006	0.007
CHA	0.008	0.015	0.014	0.01	0.033	0.045	0.021	0.016	0.011	0.04	0.037	0.027	0.018	0.082	0.036	0.019	0.007	0.017	0.005	0.008
RET	0.005	0.008	0.011	0.009	0.023	0.05	0.031	0.016	0.011	0.029	0.015	0.01	0.018	0.026	0.011	0.124	0.029	0.042	0.076	0.06
SIT	0.06	0.09	0.014	0.06	0.021	0.06	0.01	0.014	0.021	0.029	0.05	0.023	0.019	0.031	0.01	0.136	0.071	0.034	0.037	0.053
$f_b^*$	0.008	0.015	0.014	0.01	0.033	0.05	0.031	0.016	0.021	0.04	0.05	0.027	0.019	0.082	0.04	0.136	0.071	0.042	0.076	0.06
$f_b^-$	0.005	0.008	0.011	0.006	0.021	0.006	0.01	0.01	0.006	0.023	0.015	0.01	0.016	0.026	0.01	0.019	0.007	0.017	0.005	0.007

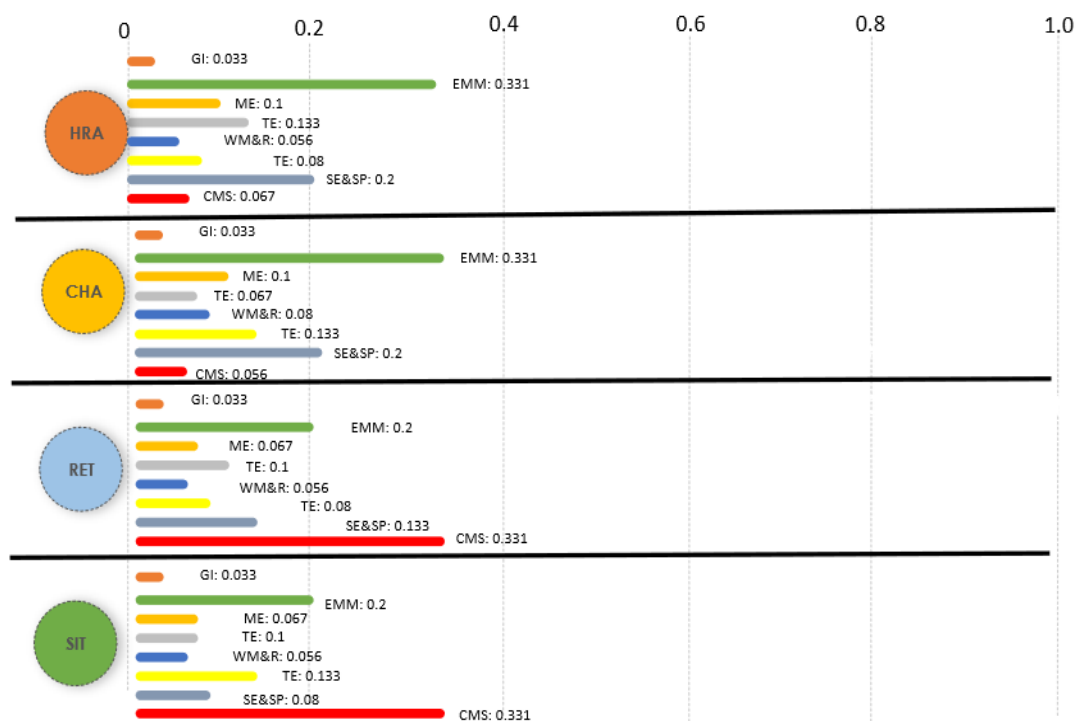


Figure 7.3. Priorities for main indicators for each port

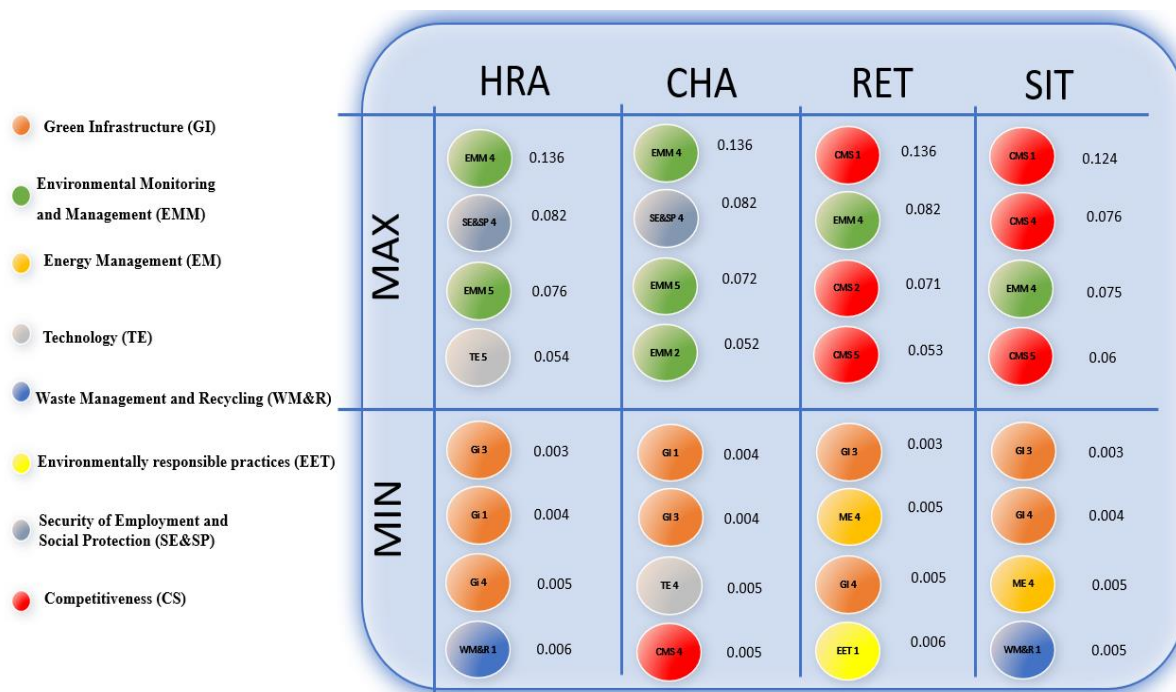


Figure 7.4. Priorities for sub-indicators for each port

The results by BWM (Table 7.6) reveal that EMM, SE&SP, and CMS are ranked higher than other indicators. On the other hand, waste management and green building were taken to the lower ranks. EMM are crucial for all ports for multiple reasons. Firstly, ports are major hubs of economic activity, facilitating trade and transportation on a global scale. EMM also allows ports to track and assess their impact on air quality, water quality, noise levels, and other environmental parameters. Additionally, another indicator that ranked prominently in our research was SE&SP. This indicator is more important for larger/medium ports than small ports. Firstly, larger/medium ports typically handle a significantly higher cargo volume, making them more attractive targets for criminal activities such as smuggling, theft, and terrorism. Secondly, larger/medium ports often have a more diverse range of stakeholders, including international shipping companies, government agencies, port authorities, and various service providers. Another indicator that is important for smaller ports is CMS. In the dynamic and evolving international trade landscape, small ports are viable alternatives to larger ports, offering specialized services, personalized attention, and cost-effective solutions. Small ports contribute to a diverse and resilient port network through their competitiveness, providing customer options and driving industry innovation. The significance of competitiveness for small ports cannot be overstated, as it is the key to their success in the face of intense competition and the pathway to their continued growth and relevance in the global trade market.

Analyzing the results (Table 7.7), it is concluded that the sub-indicators with the highest scores for the medium/small ports were EMM 4 and EMM 5. The initiatives for a sustainable development plan in SMSPs hold great significance for various reasons. Although smaller in scale compared to major international ports, these ports have a substantial environmental impact that should not be overlooked. Implementing sustainable practices in these ports can improve local air and water quality, reduce noise pollution, and protect nearby ecosystems. In a broader context, it can be said that the sustainable development of small/medium-sized ports contributes to the SDGs. For the smaller ports, sub-indicators that scored highest were from the category of “competitiveness”. The competitiveness of small ports holds particular significance compared to medium ports due to their unique characteristics and operational challenges. Small ports often operate in more constrained environments with limited resources and infrastructure. Therefore, maintaining a competitive edge becomes crucial for their survival and growth in the industry. Moreover, small ports' competitiveness is paramount in the maritime sector. These ports face unique challenges due to

their size and resources, but they also have distinct advantages, such as regional connectivity, flexibility, and adaptability.

### 7.8.2 Ports assessed using the VIKOR method.

The next phase involved ranking selected ports according to the weights of these indicators. The VIKOR methodology was used to rank the specified ports. S, R, and Q values were determined using equations (6) through (8). The Q values of the ports were compared, and the one with the lowest value was selected as the optimal one. Table 8 shows the CHA rank with the lowest grade for S and Q. Moreover,  $Q(CHA) - Q(HRA) < 1/(4-1)$  and  $Q(CHA) - Q(RET) > 1/(4-1)$ . Therefore, the VIKOR method proposes a compromise solution between CHA and HRA

**Table 7.8.** S, R, and Q values

	S	Rank	R	Rank	Q	Rank
HRA	0.27	2	0.023	1	0.03	2
CHA	0.222	1	0.026	2	0.122	1
RET	0.405	3	0.072	3	0.938	3
SIT	0.418	4	0.075	4	1	4
	$S^- = 0.222$		$R^- = 0.023$			
	$S^* = 0.418$		$R^* = 0.075$			

The results for the VIKOR method present a comprehensive comparison of sustainable indicators for ports, thus offering a clear perspective on the relative performance of different ports regarding their sustainability initiatives. The analysis helps identify which ports are the most effective in balancing these diverse sustainability factors, providing decision-makers with valuable insights into which ports lead the way in sustainable practices. By examining the compromise solutions and the corresponding rankings, stakeholders can pinpoint areas where ports excel and others where they need improvement. Based on the findings in Table 8, it is evident that CHA was ranked first, followed by HRA, RET, and SIT, respectively. The results reveal that as the best port for sustainability, a compromise between CHA and HRA is needed.



## 7.9 Conclusions

This research emphasizes the importance of integrating sustainable indicators in assessing small and medium ports. The comprehensive analysis presented here underscores the need for a holistic approach considering economic, environmental, and social dimensions. By incorporating diverse indicators, port authorities can better understand their operations, enabling them to make informed decisions that promote long-term sustainability.

The findings of this research highlight the intricate balance between environmental conservation and economic viability for small and medium ports. Achieving sustainable development requires careful consideration of both environmental and economic indicators. Our research offers insights into potential trade-offs and synergies, paving the way for port management to adopt strategies that minimize environmental impact and enhance economic resilience.

One of the additional key takeaways from this investigation is the significance of community engagement and social responsibility in the sustainable development of ports. Recognizing the social implications of port activities is crucial for fostering positive relationships with local communities. Ports that actively involve stakeholders and address social concerns are better positioned to contribute to the overall well-being of the regions they serve.

Finally, the research emphasizes the necessity of establishing robust long-term monitoring and evaluation mechanisms for sustainable indicators. Continuous assessment allows ports to track progress, identify areas for improvement, and adapt their strategies over time. By adopting a cyclical process of evaluation and adjustment, small and medium ports can remain responsive to emerging challenges and consistently align their operations with evolving sustainability goals.

The dynamic nature of the maritime industry necessitates a flexible and adaptive approach to sustainable indicators. As technological advancements and regulatory frameworks evolve, so must the indicators used to assess sustainability. Therefore, future research should delve deeper into specific aspects of sustainable development, such as integrating renewable energy sources, circular economy principles, and innovative technologies within small and medium port contexts.

## **Chapter 8- Risk management for IoT devices in ports**

## 8.1 Introduction

According to the Directive (EU) 2022/2557, Critical entities (CEs) include power grids, the transport network, and information and communication systems. CEs security is one of the most rapidly developing areas in which the EU has made significant strides in recent years (Alcaraz and Zeadally, 2015). It is a challenging process, requiring the involvement and cooperation of many different public and private sector actors. CEs provide essential services for maintaining vital societal functions, economic activities, public health and safety, and the environment (Pursiainen and Kytömaa, 2023).

In a modern critical entity, the quality of the electronic services and information and communication systems provided to stakeholders is based on the security of the information resources that support them (Kechagias et al., 2022). Shielding digital systems makes a decisive contribution to achieving the objectives of public organizations, ensuring their prestige, and enabling compliance with legal obligations and international standards (Meland et al., 2022). The complexity of digital systems, the highly dynamic operating environment of the institutions, and the risk of threats require the adoption of a holistic approach through the implementation of a security plan for the development and implementation of protection measures, ensuring that the desired level of security is established and maintained (Inkinen et al., 2019).

IoT has brought unprecedented advancements and efficiencies to various industries, including the maritime sector. More specifically, the integration of IoT devices has revolutionized port operations, allowing for enhanced monitoring, streamlined logistics, and advanced data analytics. For port operators who must contend with escalating competition, stringent regulations, and pressure to cut operational costs, IoT technology can be beneficial (Othman et al., 2022). IoT makes real-time monitoring and data analysis possible, giving port operators insights to improve their decision-making, reduce waste, and boost productivity. IoT can also help ports take a more proactive stance toward security and safety (Ye and Geng, 2023). IoT sensors can also be used to find possible safety issues, including broken equipment, spills, or unauthorized entry into prohibited areas (Bouhlal et al., 2022). Moreover, improving sustainability is another important benefit of IoT in port operations. IoT sensors can track emissions from port activities like ships and trucks, which can substantially negatively influence the environment. This information can then be utilized to create pollution reduction plans, such as encouraging electric vehicles or utilizing RES to run ports. However, this technological leap also introduces vulnerabilities

requiring a focused risk assessment and mitigation approach. Conducting a thorough risk assessment becomes imperative to understanding these critical IoT devices' potential threats and vulnerabilities. Data breaches, cyberattacks, natural disasters, sabotage, and system failures must be meticulously evaluated. Identifying and comprehending these risks is pivotal in devising effective risk management strategies encompassing preventative measures, incident response plans, and continuous monitoring.

One of the main reasons why IoT devices are more vulnerable at ports compared to other activity areas is the current complex ecosystem of ports. First, too many stakeholders can be involved in a port's operations, including shipping companies, freight forwarders, customs agents, and port authorities (Wang et al., 2022). Each infrastructure has its systems and devices connected to the port's network. This complexity creates challenges in managing the entire system's security, making it easier for attackers to find and exploit vulnerabilities. This makes them a high-value target for cybercriminals seeking to disrupt supply chains or cause economic damage, as an attack on a port's IoT devices could significantly affect global trade and commerce. Moreover, the wide range of IoT devices used at ports, including sensors, cameras, and tracking systems, creates a larger attack surface for cybercriminals (Hammi et al., 2022). The more connected the devices, the greater the risk of a security breach (Ioannis Argyriou et al., 2022).

This research focuses on the critical assessment of entities and the development of robust risk management frameworks specifically tailored to safeguard IoT devices in ports. In particular, this research focuses on addressing the need for tailored risk management strategies designed explicitly for IoT devices in ports. It is pivotal to understand the intricacies of these devices' interconnectivity, their vulnerabilities, and the potential threats they face. By delving into the functions of IoT devices, access controls, potential sabotage, as well as the effects of weather, this study seeks to provide a tool for port managers to assess the degree of risk and severity of a potential threat to IoT devices. The ultimate goal is to fortify ports against cyber threats, physical tampering, data breaches, and other possible risks associated with the proliferation of IoT devices, ensuring critical port operations' uninterrupted and secure functioning.

Risk assessment for IoT devices in ports using operational risk management (ORM) methodologies presents a promising yet underexplored area for research. Despite the increasing adoption of IoT devices in port infrastructures, there remains a significant research gap in establishing comprehensive frameworks specifically tailored for assessing risks associated with

these interconnected devices. One additional research gap lies in the development of standardized ORM methodologies that address the unique challenges posed by IoT devices within port environments. The research questions that arise through the above research gaps and will be discussed are the following:

What are the primary security threats and vulnerabilities associated with IoT devices deployed in port environments, and what strategies can be implemented to ensure resilience and continuity of port operations in the face of these vulnerabilities?

This research can be highly innovative due to its exploration of an evolving technological landscape, its addressing of complexities within interconnected networks, and its potential for substantial real-world impact on the port industry's security and operational efficiency. Integrating IoT devices within port infrastructures represents a relatively new and rapidly evolving technological landscape. Research offers the opportunity to delve deeply into this emerging field, exploring uncharted territories and offering innovative methodologies to assess and manage risks associated with these interconnected devices.

The rest of the article is organized as follows: The second part of this paper is devoted to a survey of the relevant literature concerning the developments of IoT devices and examines the most crucial threats to them. The third part analyses the steps that follow for the applied methodology. Section four discusses the research results in detail, while Section five presents the study's implications and its value to the port environment.

## **8.2 Literature review**

Ports are essential to international trade, a hub through which commodities and cargo can be moved from one country to another (Agüero-Tobar et al., 2023). The timely, efficient, and secure delivery of commodities depends on the smooth running of operations at the port. These involve many activities, including ship handling, cargo handling, customs and immigration clearance, and security measures (Wagner et al., 2022). Factors including port size and location, infrastructure and equipment availability, the competence of management and staff, and the degree to which ports have been digitalized all contribute to successful port operations (Heikkilä et al., 2022). IoT has many applications in port operations, from cargo tracking and security to traffic management and predictive maintenance (Wagner et al., 2022). Some examples of IoT tools used at ports are frequency identification, Global Positioning Systems, sensors, security cameras, and predictive

maintenance tools (Heikkilä et al., 2022). Any disruption of IoT devices at ports can have significant economic and social consequences (Sunitiyoso et al., 2022). Many tools, such as risk assessments, are used to identify potential threats and vulnerabilities and develop strategies to mitigate risks to avoid any disruption to port operations. The literature review on the risk assessment of IoT at ports involves a multidisciplinary approach that considers the technical, operational, environmental, and human factors involved in port operations.

Technical factors such as the design and security of IoT devices, communication protocols, and data management systems are essential considerations in the risk assessment of IoT at ports. (Sunitiyoso et al., 2022) propose a new risk assessment approach for cyber-physical attacks against IoT-based wireless sensor networks. It identifies and proposes novel cyber-physical characteristics, such as threat source, vulnerability, and physical impacts. The results show that 76.6% of the simulated scenarios are high-risk and that cyber-physical risk can be reduced by 71.8% with control barriers operating in both physical and cyberspace. (Wang et al., 2022) explore essential features of cooperation and the impact of information technologies on the entire supply chain and supply chain characteristics.

Operational factors such as the port's layout, cargo handling procedures, and the number of stakeholders involved in port operations are also crucial. Several studies have investigated operational factors in IoT risk assessment at ports and proposed state-of-the-art approaches to address them. For example, a study by (Lin and Cheng, 2021) identifies the importance of network segmentation in mitigating operational risks in IoT at ports. They propose the implementation of network segmentation to isolate IoT devices and systems from critical functional networks, minimizing the impact of any potential security incidents. Another study by (Kamenopoulos and Tsoutsos, 2015) focuses on monitoring and managing IoT device updates and patches to reduce port operational risks. To lessen the likelihood of vulnerabilities being exploited by cyber attackers, they suggested implementing a centralized update and patch management system across all IoT devices and systems. Additionally, human factors, such as unintentional human error and sabotage, are also critical considerations in the risk assessment of IoT at ports. Several studies have also highlighted the importance of addressing the human factor in the risk assessment of IoT at ports. (González-Cancelas et al., 2020) aim to improve maritime safety by enhancing administrative management based on human factors. The fuzzy analytic hierarchy process was used to analyze risks and threats. Administrative reform is given the highest priority, including exploring the

current crew training system, examining the marine surveyor, and inspecting the investigation system used by maritime safety investigators. (Da Rosa et al., 2023) analyze seven human risk factors using the modified risk calculation method. Two risk factors in the significant category are human carelessness and omissions and workers' limited individual experience, while operators' mistakes and faults in operations, communication misunderstandings, and execution of the job safety rules and regulations are in the moderate category. Worker's workload and stress are in the acceptable category.

Moreover, several methodologies are used for risk assessment at ports, depending on the type of risks being assessed, the complexity of the port operations, and the available resources. (Gunes et al., 2021) explore the potential for digitalization in Spanish ports using the methodology of Strengths, Weaknesses, Opportunities, and Threats. It discusses the importance of digitalization in the maritime industry, including increased efficiency, improved safety, and reduced costs. The analysis finds that while there are challenges to overcome, such as the need for investment in digital infrastructure and regulatory reforms, the potential benefits of digitalization in Spanish ports are significant.

(Smaragdakis et al., 2020) use Hazard Identification and Risk Assessment to identify potential hazards and evaluate their likelihood and impact on a container terminal. The analysis finds that the most significant safety risks in the container terminal are related to human error, such as improper handling of containers and inadequate training. This study proposes an integrated cyber risk assessment method for a container port, analyzing four exemplary cyber-attack scenarios. The method considers the cyber-physical assets of the port and applies an integrated cyber security management approach. The results show the risks for specified cyber threats, and mitigation strategies are briefly presented (Alanazi et al., 2023).

The selection of a specific methodology depends on the risks being assessed, the complexity of the port operations, and the available resources. For conducting this research, ORM was applied, a systematic process for identifying, evaluating, and mitigating risks associated with an organization's operations. In the context of port operations, ORM is a critical process for identifying and managing risks related to loading, unloading, and transporting goods and other activities such as maintenance and repair.

(Wang et al., 2023) analyze the effectiveness of ORM practices in the banking industry. The authors identify several key factors contributing to successful ORM, including risk culture,

governance, and assessment methodologies. They also emphasize the importance of communication and collaboration across different functions within an institution.

(Kamenopoulos and Tsoutsos, 2015) emphasize that photovoltaic systems that generate electricity from solar energy can pose safety hazards if not designed, installed, and maintained properly. The article provides an overview of the hazards associated with PV systems, including electrocution, fire, and structural failure. It also discusses the importance of risk assessments and implementing safety measures to mitigate these hazards.

(Wang and Wang, 2019) examine potential risks associated with the production, transportation, and storage of hydrogen fuel and the operation of fuel cell electric vehicles (FCEVs). The article uses a risk analysis methodology to assess the risks associated with introducing FCEVs in a Mediterranean town, considering population density, traffic patterns, and infrastructure. The analysis finds that the risks associated with FCEVs are generally low, and the benefits of FCEVs, such as reduced emissions and improved energy security, outweigh the risks. The article concludes by emphasizing the importance of ongoing monitoring and risk management to ensure FCEVs' safe introduction and operation.

While each methodology has unique strengths and weaknesses, ORM differs from other risk management methodologies in several ways. Firstly, ORM takes a broader perspective by encompassing a wide range of risks that arise from an organization's day-to-day operations. It goes beyond financial risks or project-specific risks and considers factors like internal processes, systems, human resources, and external events. This comprehensive approach allows organizations to identify and address risks that other methodologies may not capture, leading to a more robust risk management framework. Secondly, ORM emphasizes a proactive and holistic approach incorporating qualitative and quantitative analysis. It assesses the likelihood and impact of risks and delves into their root causes and potential interconnections. This proactive and holistic perspective enhances an organization's ability to anticipate and address risks, improving overall operational resilience.

Despite the growing interest in the risk analysis of IoT on ports, several research gaps need to be addressed to improve our understanding of the risks associated with deploying and operating IoT systems in ports. While there is growing recognition of the importance of addressing the human factors involved in the deployment and operation of IoT systems in ports, there still needs to be a greater understanding of the specific factors contributing to security incidents and how they can



be addressed. Moreover, cybersecurity is a critical concern in the deployment and operation of IoT systems in ports, and it is essential to consider the potential cyber threats and vulnerabilities associated with these systems. Therefore, further research must be conducted on the specific cybersecurity risks associated with IoT systems in ports and how these risks can be effectively managed. In addition, the COVID-19 pandemic has significantly impacted port operations, highlighting the need for effective risk management strategies to address pandemics and other global crises. However, there has been limited research on the specific risks and vulnerabilities associated with IoT systems in ports in the context of pandemics. Finally, natural disasters are likely to significantly impact port operations, which may impact risk analysis practices. There is a need for more research on how climate change may impact risk analysis practices and how these practices can be adapted to account for changing climate conditions. Addressing these research gaps will require a broad and holistic approach, considering the perspectives of different stakeholders and the various contextual factors that may affect the deployment and operation of IoT systems in ports. The analysis revealed the hazards related to IoT devices at ports operations represents in Table 8.1.

**Table 8.1.** List of the potential IoT hazards.

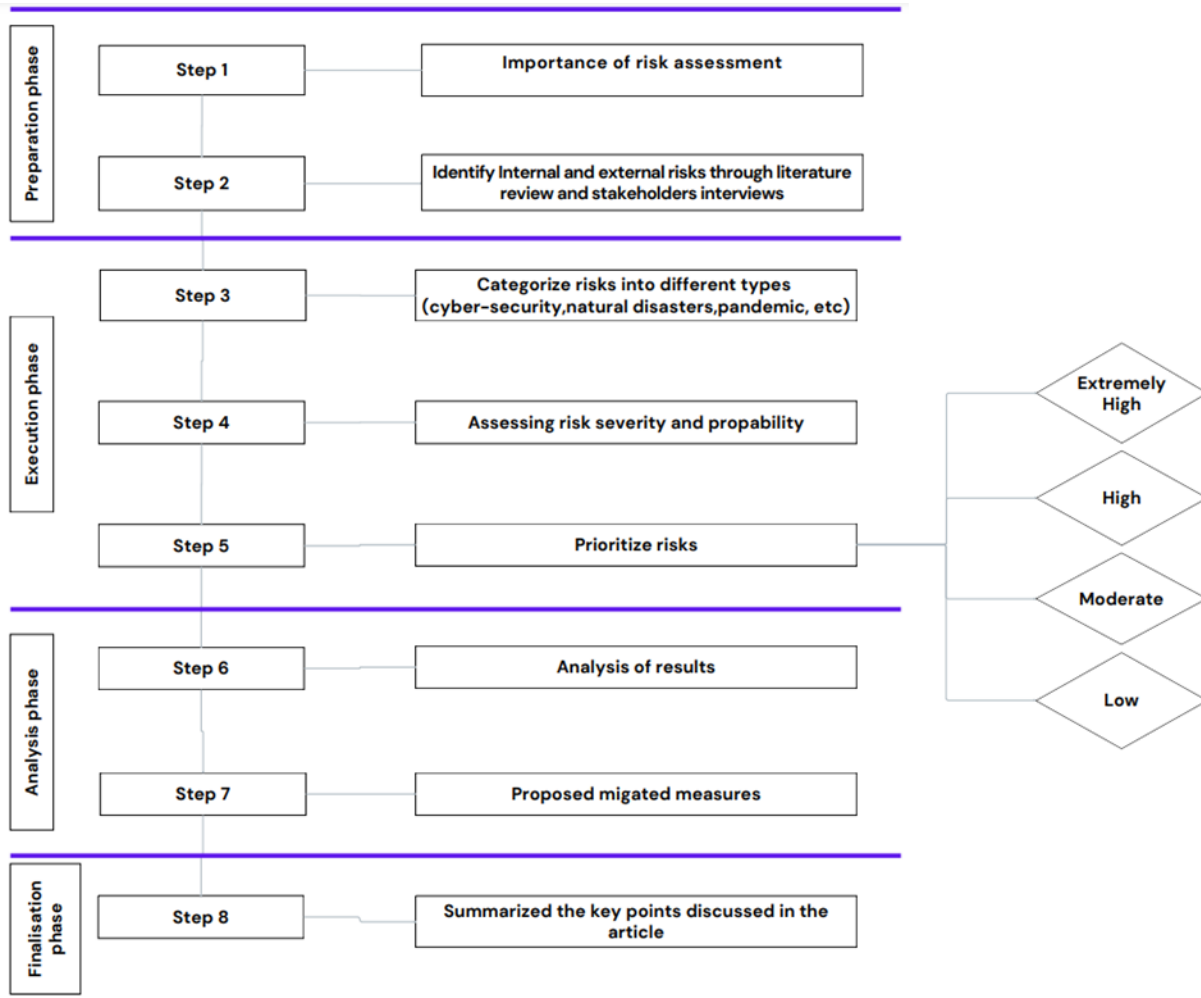
Source		Hazards	Effect to	Literature
<b>Terrorism</b>				
Attack from chemical agent	TE 1	Damage to IoT devices, Health	Human, Environment, Equipment	(Shokry et al., 2022)
Cyber-attack	TE 2	Damage to IoT devices	Equipment	(Shokry et al., 2022)
Armed person	TE 3	Damage to IoT devices, Health	Human, Equipment	(Hughes-Lartey et al., 2021)
Explosive device explosion with loss of manpower	TE 4	Health hazard	Human	(Tuptuk and Hailes, 2018)
Explosive device explosion with loss of logistical equipment	TE 5	Damage to IoT devices	Equipment	(Caballini et al., 2023)
<b>Human effect</b>				
Unintentional human error	HE 1	Damage to IoT devices	Human, Equipment	(Yucel et al., 2012)
Sabotage	HE 2	Damage to IoT devices	Human, Equipment	(Febriani et al., 2023; Moosavi et al., 2022; Zhao and Tang, 2023)
<b>Pandemic</b>				
Increased demand for the use of IoT devices	PE 1	Damage to IoT devices	Equipment	
Staff reduction	PE 2	Health hazard	Human	(Rak et al., 2021; Wang et al., 2022)
Supply chain disruptions	PE 3	Damage to IoT devices	Equipment	(Garcia-Alonso et al., 2020)
<b>Natural disasters</b>				
Heavy rainfall	ND 1	Damage to IoT devices	Equipment	(Hu et al., 2023; Thouti et al., 2022)
Earthquake	ND 2	Damage to IoT devices	Human, Environment, Equipment	(Huang et al., 2023)
High temperature	ND 3	Damage to IoT devices	Equipment	(Baldini et al., 2023)
Low temperature	ND 4	Damage to IoT devices	Equipment	
Thunder	ND 5	Damage to IoT devices	Equipment	
Hail	ND 6	Damage to IoT devices	Equipment	(Baldini et al., 2023)
Moisture	ND 7	Damage to IoT devices	Equipment	(Shen et al., 2021)

<b>Maintenance</b>				
Power outage	ME 1	Damage to IoT devices	Equipment	(Chaves et al., 2017)
Physiological wear and tear of equipment	ME 2	Damage to IoT devices	Equipment	(Hussain et al., 2021)
Internet network loss	ME 3	Damage to IoT devices	Equipment	(Færøy et al., 2023)
Power disturbance	ME 4	Damage to IoT devices	Equipment	(Chiappetta, 2017)
Short circuit	ME 5	Damage to IoT devices	Equipment	
<b>Cyber security</b>				
Malware	CE 1	Damage to IoT devices	Equipment	(Tsavdaroglou et al., 2018)
Phishing	CE 2	Damage to IoT devices	Equipment	(Hussain et al., 2021)
Access to wi-fi	CE 3	Damage to IoT devices	Equipment	(Chiappetta, 2017; Færøy et al., 2023)

## 8.3 Methodology

### 8.3.1 Mathematical tool and model

The following flowchart (figure 8.1) represents the sequence of steps that were followed for our methodology.



**Figure 8.1.** Flowchart: Steps of the proposed methodology

ORM is a critical process for any organization looking to ensure the success of its operations. It is a systematic approach to identifying, assessing, and managing risks from people, systems, processes, and external events affecting an organization's objectives. ORM is key, as it helps organizations avoid losses and reputational damage and ensures they can continue operating effectively in the face of uncertainty.

The first step in ORM is risk identification. This involves identifying and categorizing risks based on their potential impact and likelihood of occurrence. Risk identification can be made through the review of historical data, the conduct of risk assessments, and the analysis of business processes. Organizations can proactively mitigate risks and minimize their potential impact by identifying them early. Once risks have been identified, the next step is risk assessment. This involves analyzing the likelihood and consequences of the risk occurring and the effectiveness of current controls in mitigating the risk. By assessing risks, organizations can determine which ones require the most attention and prioritize their risk management efforts accordingly.

The third step in ORM is risk mitigation. Organizations should develop strategies to mitigate the identified risks based on the assessment. This may involve implementing new controls or improving existing ones, as well as establishing contingency plans to manage the impact of the risk should it occur. The effectiveness of risk mitigation strategies should be regularly evaluated to ensure that they remain effective and relevant. Monitoring and reporting are also critical aspects of ORM. Organizations should monitor the effectiveness of their controls and report on any new risks that may arise. This involves ongoing risk assessment and reporting to senior management to ensure acknowledgment of potential new risks. This data can inform decision-making and ensure that the organization remains agile and responsive in the face of uncertainty.

Finally, ORM is an ongoing process that requires continuous improvement. This involves regularly reviewing the risk management strategies to ensure that they remain effective and relevant, as well as incorporating new risks and changing business processes into the risk management framework. By adopting a continuous improvement approach to ORM, organizations can stay ahead of potential risks and ensure the long-term success of their operations.

The Risk Assessment Matrix (Table 8.2) is used to assign Risk Assessment Codes to each hazard that may be experienced while completing an objective. This matrix is based on the concept that  $\text{Risk} = \text{Probability} \times \text{Severity}$ . It consists of two areas:

- Probability categories; and
- Severity/consequences categories.

The probability of each possible outcome is displayed along the top axis of the matrix and has been divided into five distinct categories: almost certain, likely, possible, unlikely, and rare. The severity of an incident is measured by its impact on achieving objectives. The left side of the matrix displays four categories used to rate the severity: catastrophic, critical, moderate, and negligible.

**Table 8.2.** Risk Assessment Matrix

Risk Assessment Matrix		Probability										
		5	Almost Certain	4	Likely	3	Possible	2	Unlikely	1	Rare	0
Severity	Catastrophic	4	Extremely High	Extremely High	Extremely High	Extremely High	Extremely High	High	High	Moderate	Moderate	Moderate
	Critical	3	Extremely High	Extremely High	Extremely High	Extremely High	High	High	Moderate	Moderate	Moderate	Moderate
	Moderate	2	High	High	High	High	Moderate	Moderate	Low	Low	Low	Low
	Negligible	1	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low	Low
		0	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

The cells of the matrix are typically color-coded or labeled to represent the level of risk associated with each cell. For example, the cells in the upper right corner of the matrix, where risks have a high likelihood and impact, might be labeled "critical" or colored red to indicate the need for immediate attention and action. The Risk Assessment Matrix is a valuable tool for risk management because it helps prioritize risks and allocate resources accordingly. Risks that fall into the higher-risk categories should be addressed first, while lower-risk items can be addressed later or monitored closely.

In addition to identifying and prioritizing risks, the Risk Assessment Matrix can also help organizations make informed decisions about risk mitigation strategies. For example, risks that fall into the "critical" category may require more proactive measures, such as developing a contingency plan or investing in additional resources to minimize their impact. It is important to note that the Risk Assessment Matrix should be regularly reviewed and updated as new risks arise or existing risks change. This ensures that organizations continuously monitor potential threats and take appropriate actions to mitigate them.

### **8.3.2 Description of survey phases**

The research was conducted to develop risk management strategies for ports. Initially, the research aimed to identify events that were to be examined through a literature review. Twenty-five events were selected after a comprehensive literature review and given to eighteen experts (4 researchers, 4 users and sellers of IoT devices, 3 policymakers, and 3 engineers) for evaluation and ranking and then divided into six broad categories. The experts who participated in the survey were selected because of their experience in port facility operations, including developing and implementing technologies to improve safety and functionality. The research was conducted using a questionnaire and interviews. The questionnaire requested the experts to evaluate the degree of probability and severity of each event against the Likert Scale [probability (1: Rare to 5: Almost Certain) and the severity (1: Negligible to 4: Catastrophic) correspondingly], whereas the follow-up interviews aimed at allowing the respondents to justify and elaborate on their answers. In addition, the respondents were interviewed to explain their responses regarding the potential risks associated with IoT devices. The data collection process lasted roughly two months (early March to late April 2023).

## **8.4 Results**

### **8.4.1 By factor**

#### **8.4.4.1.Terrorism**

The findings indicate a possible probability (2.9) and high severity (3.6) of cyber-attacks due to terrorist attacks. According to the respondents' explanations, the results can be explained by the fact that ports play a critical role in the global market chain, and any disruption to the port's infrastructure may result in significant economic losses and delays in the supply chain. According to the ORM, the results depict an extremely high risk (10.1) of cyber-attacks due to terrorism, affecting the proper functioning of IoT devices.

The answers provided by the respondents depict that the probability of a chemical attack at a port cannot be completely ruled out. The combination of strict regulations, however, security measures, and safety protocols in place significantly reduces the probability (1.6) of such an event occurring. The low portability result can be explained because the use of chemical agents in terrorist attacks is complex and requires specialised knowledge and equipment. On the other hand, the severity of

a terrorist attack on IoT devices in ports using chemical factors is ranked between moderate and critical (2.5). Based on the insights provided by the respondents, this result can be explained because such an attack could have devastating consequences on port operations, public health, and the environment. ORM's result (4.2) on this event shows a moderate risk.

According to the respondents, the probability of an attack by an armed man on IoT devices at ports is unlikely (1.8). The comments received from the respondents provide a further understanding of why the probability is unlikely, revealing that security checks and other screening measures are in place to ensure that it is difficult for an armed person to access port infrastructures. These measures act as deterrents to would-be attackers, making it difficult for them to gain entry into port facilities undetected. Conversely, the severity (3.3) of an attack by an armed man on IoT cannot be underestimated. A successful attack can result in numerous fatalities and injuries, causing significant social and economic distress. The result of the ORM (4) of armed attack on IoT devices at ports ranks as moderate risk. Mitigating terrorist attacks on IoT devices at ports demands a multifaceted approach encompassing physical and network security enhancements, employee training, incident response planning, collaboration, and regulatory compliance. By implementing these measures, port authorities can minimize vulnerabilities, enhance situational awareness, and maintain the continuity of port operations. The probability of IoT devices at ports being affected by terrorist attacks involving explosives is possible (approximately 3), given the increased vulnerability of ports, the sophistication of attack methods, inadequate security measures, potential insider threats, and the implications for economic and national security. The severity (approximately 3) of a terrorist attack involving explosives on IoT devices at ports is critical due to the potential disruption of port operations, economic implications, safety and security risks, environmental consequences, and psychological and societal impacts. According to the ORM results, these events present high/extremely high risk.

#### **8.4.4.2. Pandemic**

The responses from the participants highlight that the likelihood of another pandemic is low. While it is impossible to eliminate the risk of pandemics, the collective experience, scientific advancements, and strengthened global cooperation resulting from the COVID-19 pandemic have significantly lowered the likelihood of another pandemic of similar magnitude. By building on the lessons learned and continuing to invest in preparedness, surveillance, and research, the world is



better prepared to detect and respond swiftly to emerging threats, minimizing their impact and preventing widespread outbreaks. On the other side, the results indicate that in case of a new pandemic, there is a likely probability of an increase in demand for IoT devices at ports (3.9), staff reduction (3.7), and disruption to the supply chain (3.5). For example, the COVID-19 pandemic has increased the use of IoT devices at ports for several reasons. Firstly, the pandemic has accelerated the maritime industry's digital transformation, with more organizations adopting remote work and digital technologies to maintain operations. IoT devices are being used to enable remote work, reduce face-to-face interactions, and manage logistics and supply chain operations. Secondly, as countries worldwide implemented lockdowns and travel restrictions, the movement of goods and people was severely impacted. This disruption can lead to shortages of critical goods and raw materials, delayed shipments, and increased costs for businesses and consumers, including those utilizing IoT technology at ports. Manufacturing disruption is another challenge facing supply chains using IoT technology at ports during the pandemic. As factories and plants were forced to shut down or reduce operations, the production of goods was significantly impacted. This led to shortages of critical components and raw materials, further exacerbating the disruptions in supply chains utilizing IoT technology at ports. In addition to the abovementioned factors, the pandemic has highlighted the importance of cutting down personnel. However, as IoT devices require human oversight and decision-making, the reduction in personnel could impact their reliability and performance. Suppose there are fewer personnel available to perform routine maintenance and repairs. In that case, the devices may be more prone to failure or breakdown, which could impact the efficiency and safety of port operations. Furthermore, the survey responses reveal that in case of a pandemic, the effects on the operation of IoT devices will be severe. Finally, using the ORM methodology for all three events examined, the overall result highlighted the extremely high risk for the proper operation of IoT devices during a pandemic. Mitigating the impact of a pandemic on IoT devices at ports requires specific measures to ensure their uninterrupted functionality and minimize the risk of contamination. Firstly, implementing remote management and monitoring systems for IoT devices can help reduce the reliance on physical interaction. Secondly, ports can execute a thorough sanitation and hygiene protocol to ensure the cleanliness of IoT devices. Regular cleaning and disinfection of devices and their surrounding areas can help reduce the risk of virus transmission. Lastly, developing a comprehensive business continuity plan specific to IoT devices is crucial. This plan should outline procedures and strategies

for maintaining IoT device operations during a pandemic. It should include provisions for remote maintenance, alternative supply chains for necessary components, and guidelines for handling device failures or disruptions.

#### **8.4.4.3. Human effect**

Based on the feedback provided by the respondents, there is a possible probability (2.8) of malfunctioning IoT devices at ports due to human factors. However, despite technological advancements and the increasing use of IoT devices in ports, human error remains a significant factor that can lead to the malfunctioning or failure of IoT devices. For example, one reason for the possible probability of dysfunction of IoT devices at ports due to human factors is the lack of awareness and training among port personnel. Moreover, the potential for malevolent action on IoT devices at ports is a growing concern, given the increasing reliance on these devices for critical infrastructure and operations. A malicious insider could cause physical damage to equipment or disrupt critical systems, leading to shipping delays and financial losses. Each of the above events can create serious problems for the unobtrusive operation of IoT devices. The ORM methodology findings indicate a high risk of unintentional human error (7.8) and an extremely high risk of sabotage. Mitigating human error and sabotage on IoT devices at ports requires a multi-faceted approach focusing on training and awareness, access control, incident reporting, and continuous monitoring. By implementing these measures, ports can minimize the risks associated with human factors and intentional sabotage, ensuring the security, reliability, and continuity of IoT devices and safeguarding critical ports.

#### **8.4.4.4. Cyberattacks**

In today's interconnected world, the increasing reliance on IoT devices at ports has brought numerous benefits regarding efficiency and automation. However, this interconnectedness also introduces the risk of cyber-attacks targeting these devices. Cyber-attacks can target critical systems, such as cargo tracking, vessel communication, or security surveillance, compromising the overall functionality and safety of the port. The probability of IoT devices at ports being affected by cyber-attacks such as hacking, malware, phishing attacks, and network loss is possible as the growing number of IoT devices at ports provides a larger attack surface for cybercriminals. The respondents mentioned several reasons for the likely probability of occurrence. Firstly, each connected device can be a potential entry point for unauthorized access or exploitation. Secondly,

the port environment is an attractive target for cybercriminals due to the potential impact of a successful attack. On the other hand, the severity of cyberattacks affecting IoT devices at ports is also considered catastrophic due to several critical factors. The interconnected nature of IoT devices, the value of the data they generate, and the complexity of securing their ecosystem all contribute to the potential severity of cyber-attacks. A successful attack on one device can quickly spread to other connected devices, compromising the entire port infrastructure. Disrupting port operations can cause significant economic losses, impact global supply chains, and even pose risks to national security. The result by ORM indicates that the overall risk due to cyber-attacks is extremely high. Implementing tight security protocols, employing network segmentation and isolation, updating and patching regularly, and training employees on cybersecurity best practices are some of the mitigating measures to protect critical infrastructure and IoT devices at ports from cyber-attacks and ensure the continuity of port operations.

#### **8.4.4.5. Maintenance**

Maintaining IoT devices at ports is a critical task that requires regular monitoring, firmware updates, and a robust asset management system. The comments provided by the respondents emphasize that the probability of maintenance issues related to network loss, circuit outages, and power interruptions for IoT devices at ports can be attributed to a combination of factors. The presence of robust infrastructure, professional installation and maintenance practices, comprehensive monitoring systems, preventive maintenance approaches, and technological advancements collectively minimize the probability of such issues. On the other hand, these devices work non-stop. Ports operate round the clock, and IoT devices may be required to work continuously without a break. The constant use of these devices can cause components to wear out, leading to reduced performance and potential failure. In addition, installing IoT devices in areas exposed to heavy machinery or equipment can lead to increased wear and tear. Vibrations and shocks from these sources can cause damage to the devices' components and lead to premature failure. Based on the feedback provided by the respondents, the critical severity of maintenance issues can be attributed to the presence of redundancy systems, well-prepared contingency plans, proactive monitoring and maintenance practices, technological advancements, and efforts to reduce single points of failure. Ports recognize the significance of these issues and implement measures to minimize the severity and duration of maintenance requirements, ensuring reliable

and uninterrupted operation of IoT devices to support efficient port management. Finally, the results from ORM indicate that, overall, there is a medium risk for this category. By investing in these areas, ports can proactively manage their IoT devices, ensuring reliable and uninterrupted operation and optimizing the efficiency of port operations. Mitigating maintenance challenges for IoT devices at ports requires effective strategies and measures to ensure optimal performance and longevity. Firstly, implementing a proactive maintenance approach is essential. This involves conducting regular inspections, preventive maintenance, and predictive analytics to identify potential issues before they escalate into major problems. Secondly, establishing a comprehensive asset management system is crucial for effectively maintaining IoT devices at ports. This involves keeping an up-to-date inventory of all devices, tracking their locations, and recording their maintenance history.

#### **8.4.4.6. Natural disaster**

With the increasing use of IoT devices at ports, there is a growing concern about their vulnerability to environmental factors such as temperature or extreme weather phenomena. While high and low temperatures can potentially affect the performance and longevity of IoT devices, the results and comments provided by the respondents emphasize that the likelihood of such effects is considered medium. One of the primary reasons why the probability of temperature affecting IoT devices at ports is considered of medium importance is due to technological advances. Moreover, modern IoT devices are designed to withstand a wide range of temperatures, making them less susceptible to damage or malfunction due to high or low temperatures. While the probability of temperature changes affecting IoT devices at ports may be unlikely/possible, the severity of such effects can be moderate. High temperatures can cause IoT devices to overheat, leading to performance issues, hardware damage, and even system failure. In ports, high temperatures can be caused by extreme weather conditions or proximity to heat-emitting equipment, such as machinery or vehicles. Low temperatures, however, can cause devices to freeze or become unresponsive, potentially leading to system downtime and decreased productivity. Based on the ORM results, the risk is moderate.

Weather phenomena such as rainstorms, hail, thunder, or natural disasters, e.g., floods, can also pose significant risks to IoT devices. Firstly, the durability and quality of IoT devices play a crucial role in their ability to withstand extreme weather conditions [54]. Devices not designed to operate in harsh weather environments are more likely to fail, resulting in potential damage or loss of

critical data. Secondly, the location of the IoT devices is essential. Although the probability of affecting IoT devices at ports due to rainstorms, hail, or thunder is considered unlikely/possible, the severity of the impact can be high/moderate. A damaged or malfunctioning IoT device can delay or disrupt port operations, leading to financial losses and reduced productivity. Moreover, a malfunctioning device can compromise the safety and security of the port, potentially resulting in accidents or security breaches. ORM outcomes highlight the high/moderate risk for these events. Earthquakes are also natural disasters that can devastate infrastructure and technology. Several factors, including the geological history of the area and the proximity to active fault lines, determine the probability of an earthquake occurring at a particular location. In general, areas located close to fault lines have a higher likelihood of experiencing earthquakes. On the other hand, the severity of the impact of an earthquake on IoT devices at ports depends on several factors, including the magnitude of the earthquake, the distance from the epicenter, and the strength of the infrastructure. In general, the higher the earthquake's magnitude, the more severe the impact on IoT devices. The findings from ORM present low risk as a result of the earthquake. Mitigating the effects of natural disasters on IoT devices at ports requires a proactive and comprehensive approach. By protecting physical infrastructure, ensuring resilient network connectivity, implementing remote monitoring capabilities, establishing data backup and recovery mechanisms, and investing in training and preparedness, ports can enhance their resilience and minimize the disruptions caused by natural disasters. These measures protect critical IoT devices and contribute to the overall safety, efficiency, and continuity of port operations in the face of natural disasters.

#### **8.4.2 Overall results**

The analysis of results on risk assessment for IoT devices reveals several key findings, as depicted in Table 8.3. Firstly, it is evident that IoT devices possess vulnerabilities that expose them to various risks. According to Figure 8.3, the results indicate that factors such as CE 1, CE 2, CE 3, PE 1, PE 2, PE 3, HE 2, ME 3, TE 2 and TE 4. present an extremely high risk. Additionally, the analysis highlights the high risk for many factors such as HE 1, ND 1, TE 5, and NP 7. Furthermore, it's also clear from the results that factors like ND 2, ND 3, ND 4, ND 5, ND 6, TE 1, TE3, and ME 2 pose a moderate risk. Therefore, manufacturers, developers, and users must prioritize security measures and adopt robust risk mitigation strategies to safeguard IoT devices according to the risk analysis.

**Table 8.3.** Risk Matrix based on results

Risk Assessment Matrix		Probability				
		5 Almost Certain	4 Likely	3 Possible	2 Unlikely	1 Rare 0
Severity	4 Catastrophic	Grade:20-Extremely High	Grade:16-Extremely High CE3, CE2, PE2, PE3	Grade:12-Extremely High CE1, TE2, TE4, HE2, ME3	Grade:8- High	Grade:4-Moderate
	3 Critical	Grade:15-Extremely High	Grade:12-Extremely High PE1	Grade:9-High ME1, ME4, HE1, ME5, TE5, NP7, ND1	Grade: 6-Moderate ND5, TE1, TE3, ND6, ME2	Grade:3-Moderate
	2 Moderate	Grade:10-High	Grade:8-High	Grade:6-Moderate ND3, ND4, ND2	Grade:4-Low	Grade:2-Low
	1 Negligible	Grade:5-Moderate	Grade:4-Moderate	Grade:3-Low	Grade:2-Low	Grade:1-Low
	0					

### 8.4.3 Discussion of the results

The expected score range would be 0 to 25. Table 8.4 indicates that the most risky scenarios had the highest mean score.

**Table 8.4.** Assessment of scenarios.

Scenario	Mean Score	Standard Deviation	Confidence level
CE2	11.6	4.15	1.9
CE3	12.3	3.50	1.6
PE2	13.1	3.3	1.5
PE3	11.5	2.7	1.2

The scenarios with the highest mean score are related to cyber security threats (phishing/wi-fi access). The risk of phishing and unauthorized access to Wi-Fi at ports is notably high due to the critical nature of port operations and the vast array of interconnected systems and devices. With numerous personnel, contractors, and visitors accessing Wi-Fi networks, there's an increased likelihood of unwittingly falling victim to phishing attempts or inadvertently granting unauthorized access to critical systems. The sprawling and diverse network infrastructure at ports, often comprising legacy systems alongside modern technology, creates complexities in maintaining a robust security posture, leaving potential vulnerabilities that cyber attackers can exploit. A

comprehensive security strategy should be adopted to minimize the risk of phishing and unauthorized access to Wi-Fi at ports. This involves the implementation of robust encryption protocols for Wi-Fi networks, frequent password changes, and using strong authentication methods. Network segmentation helps isolate critical systems from public access, while regular software updates and patch management address known vulnerabilities. Firewalls, intrusion detection systems, and employee cybersecurity training are pivotal in detecting and preventing phishing attempts and other cyber threats. Additionally, routine security audits, physical access controls, and compliance with relevant regulations form essential components of a multifaceted approach to fortify the port's cybersecurity infrastructure.

The next most critical scenarios are related to the pandemic (increased demand for IoT devices and staff reduction). The risk posed by a pandemic at ports is notably elevated due to the confluence of increased reliance on IoT devices and the challenges associated with staff reductions. Pandemics often necessitate changes in operational procedures at ports, leading to heightened demand for IoT devices to enable remote monitoring, automated processes, and enhanced efficiency. However, this increased reliance on IoT devices can widen the attack surface, potentially exposing ports to cyber threats, as these devices may have security vulnerabilities or lack adequate protection measures. Simultaneously, staff reductions and operational adjustments due to health concerns and safety protocols can strain resources, limiting the workforce available to manage and secure the expanded IoT infrastructure effectively. This reduction in personnel can result in inadequate oversight, slower response times to security incidents, and difficulties in maintaining stringent cybersecurity protocols, thus amplifying the risk of cyber-attacks and disruptions to port operations during a pandemic. Regular staff training and awareness programs should focus on cybersecurity and pandemic-specific safety protocols, ensuring employees can effectively handle operational challenges and cybersecurity risks.

## **8.5 Conclusions**

This research has highlighted the critical importance of effective risk management strategies for IoT devices within port environments. The rapid proliferation of interconnected devices in ports has presented unprecedented opportunities and daunting challenges regarding security, safety, and operational efficiency. Through an extensive analysis of risk factors, vulnerabilities, and potential threats associated with IoT devices, this research has underscored the necessity for comprehensive risk management frameworks explicitly tailored to the port industry. The findings of this study emphasize the need for a multidimensional approach to risk management, integrating technological solutions, policy frameworks, and collaborative efforts among stakeholders.

As the IoT continues to expand its footprint within port ecosystems, the recommendations and insights offered in this Thesis serve as a foundation for developing proactive risk management strategies. Implementing these strategies will fortify the security of IoT devices and ensure the resilience and reliability of port operations in the face of potential threats. Ultimately, this research contributes to the advancement of knowledge in the field of risk management for IoT devices in ports and provides a roadmap for safeguarding these critical infrastructures in an increasingly interconnected world.

The analysis of this research revealed that the most significant risks affecting IoT devices at ports come from cybersecurity threats. IoT devices are vulnerable to cyber-attacks due to their connectivity and the sensitive data they transmit. A cybersecurity breach could lead to data theft, system disruptions, and even physical harm to port personnel. Such an attack could also compromise port operations' safety and security, leading to cargo loss or significant delays. Moreover, the assessment of the findings unveiled that physical disasters are also significant risks that affect IoT devices at ports. These devices are exposed to various environmental conditions, such as extreme temperatures, humidity, and weather conditions, that could lead to physical damage. The consequences of a physical disaster impacting IoT devices at ports can include cargo handling delays, supply chain visibility disruptions, increased security risks, compromised safety protocols, and financial losses for port operators and businesses relying on port services. The findings also highlight the importance of implementing robust disaster recovery plans and cybersecurity measures to mitigate such risks and ensure the continuity of port operations.

Future work on risk management for IoT devices in ports should center on initiatives that emphasize the development and adoption of standardized security protocols tailored explicitly for the diverse



array of IoT devices utilized within ports will be fundamental. This entails establishing comprehensive encryption methods, stringent authentication mechanisms, and robust access controls. Alongside regulatory enhancements, integrating emerging technologies such as Artificial Intelligence and Machine Learning (ML) should be explored to bolster threat detection capabilities and pre-emptive risk mitigation strategies. By incorporating these future-focused recommendations, the port industry can pave the way for resilient, secure, and ethically sound IoT device deployments while ensuring the continuity of critical operations.

This methodology for risk management on IoT devices at ports can be adapted and utilized in other sectors beyond the maritime industry. The principles and framework of risk assessment can be applied to various domains incorporating IoT devices, enabling organizations to identify, analyze, and mitigate risks effectively, such as healthcare, manufacturing, transportation, and energy.

## **Chapter 9-Conclusions**

## **9.1 Discussion on the objectives of PhD Thesis**

As the global economy evolves, SMSPs are poised to play an increasingly pivotal role in facilitating trade and connectivity. The insights gleaned from this research contribute to the academic discourse and offer practical implications for policymakers and practitioners. Through an exhaustive examination of existing literature, case studies, and empirical analyses, this research has contributed to a nuanced understanding of the unique dynamics and considerations that underpin effective planning for SMSPs. The knowledge generated through this PhD Thesis aims to inform and guide the sustainable development and planning of SMSPs, ensuring their resilience and relevance in the ever-changing landscape of maritime transportation.

The findings underscore the importance of adopting a holistic approach integrating diverse elements such as environmental sustainability, economic viability, and social impact into the planning process. The Thesis has highlighted the need for adaptive and resilient strategies to address the maritime industry's evolving nature, considering technological advancements, climate change, and geopolitical shifts. This PhD Thesis systematically fulfilled its defined objectives as follows:

### **9.1.a Providing a guide for effective and efficient planning**

This PhD Thesis endeavors to provide a comprehensive and valuable guide for effective and efficient planning to ensure the sustainability of SMPSs. The significance of small and medium ports in global trade and regional development cannot be overstated. These ports are vital to economic growth and prosperity in many regions and nations. However, their sustainability is increasingly challenged by a complex web of economic, environmental, and operational factors.

Through an extensive review of the literature, empirical analysis, and the development of practical frameworks, this Thesis has made significant contributions to our understanding of the challenges and opportunities facing SMSPs. It has offered a nuanced perspective on the multifaceted nature of sustainability, addressing economic, environmental, social, and operational dimensions. By doing so, it has recognized the interdependence of these facets and highlighted the importance of a holistic approach to planning for sustainability.

This research has also proposed a structured framework for decision-making and planning that integrates critical elements such as stakeholder engagement, risk assessment, and technology integration. This framework empowers port authorities, policymakers, and industry stakeholders to make informed choices that align with their sustainability goals.

In an era marked by the imperative of addressing climate change and the growing importance of global supply chains, the findings and recommendations of this research offer a timely and practical

guide for navigating the challenges faced by SMSPs. By integrating sustainability principles into their planning processes, these ports can become more resilient, environmentally responsible, and economically competitive, ultimately contributing to the well-being of their communities.

This Thesis serves as a call to action for all stakeholders involved in the operation and governance of these ports. By implementing the recommendations in this research, we can collectively contribute to a more sustainable and resilient future where SMSPs thrive as engines of growth and innovation. Global trade, technology, and environmental considerations are continuously evolving. Thus, the guide provided in this Thesis should serve as a dynamic tool that can be updated and refined to meet the ever-changing demands and challenges facing SMSPs.

#### **9.1.b Examining the use of the applied methodologies as decision-making tools to optimize sustainability.**

This PhD Thesis has comprehensively examined applied methodologies, specifically multicriteria decision-making tools, as powerful instruments for optimizing sustainability in various contexts. Through an extensive review of existing literature, empirical analysis, and the development of practical frameworks, this Thesis has made substantial contributions to our understanding of the role of applied methodologies in enhancing sustainability. It has emphasized the inherent complexity of sustainability challenges and the need for systematic, data-driven decision-making processes to navigate these complexities effectively. It is evident that integrating applied methodologies, particularly multicriteria decision-making tools, is indispensable for addressing the pressing sustainability issues of our time. The findings of this research underscore the potential of applied methodologies in driving solutions that are not only sustainable but also pragmatic and adaptable.

The research has elucidated the advantages of multicriteria decision-making tools in facilitating the evaluation and prioritization of diverse sustainability criteria. By simultaneously considering economic, environmental, social, and operational factors, these methodologies offer a holistic perspective that promotes well-informed, balanced, and integrated decision-making. Furthermore, they provide a structured and transparent approach to assessing trade-offs and uncertainties, which is crucial in sustainability contexts where conflicting goals and uncertainties are commonplace. In practical terms, the research has proposed a flexible framework for applying multicriteria methodologies in specific frameworks.

### **9.1.c Ranking of priorities for port sustainability improvement through stakeholders' perspectives**

Sustainable port management is an urgent and evolving challenge, as ports play a pivotal role in global trade, regional development, and environmental stewardship. To address these complex and interconnected issues effectively, it is imperative to adopt a comprehensive and inclusive approach, considering the diverse perspectives of stakeholders. This doctoral research has delved deeply into the critical realm of port sustainability, explicitly focusing on prioritizing improvements as perceived through the multifaceted lens of stakeholders. It has underscored the significance of incorporating various viewpoints, such as those of port authorities, local communities, shipping companies, environmental groups, and governmental agencies, in shaping sustainability strategies. Through an extensive exploration of the existing literature, empirical studies, and the development of a robust framework, this Thesis has made substantial contributions to our understanding of how stakeholders perceive and rank the priorities for enhancing port sustainability. The research has illuminated the complexities of stakeholder engagement and the challenges in reconciling their often divergent interests. It has emphasized the importance of transparency, communication, and collaboration in the decision-making processes that influence the sustainable development of ports. The findings presented in this Thesis have identified the critical priorities for port sustainability improvements and elucidated the reasons and motivations underlying stakeholder rankings, providing valuable insights for port authorities and policymakers.

Furthermore, this research has developed a flexible framework for integrating stakeholder perspectives into the decision-making process, enabling port managers to prioritize sustainability initiatives that align with the interests and concerns of the various stakeholders. This framework is a practical guide for ports seeking to navigate the complex sustainability landscape while fostering more robust relationships with their communities and stakeholders.

This Thesis calls upon port authorities, industry players, and policymakers to heed stakeholders' voices and use the findings and recommendations provided here as a catalyst for meaningful change. We can foster more inclusive, equitable, and environmentally responsible port operations by actively engaging with stakeholders and incorporating their perspectives into port sustainability strategies.

#### **9.1.d Examining the degree of responsiveness /acceptance of stakeholders to the proposed sustainable development measures.**

Sustainable development is essential for addressing our time's challenges, including environmental degradation, social equity, and economic viability. To advance sustainable development successfully, it is paramount to engage stakeholders in the process and understand their perspectives, concerns, and willingness to embrace proposed measures.

By meticulously exploring existing literature, empirical analysis, and developing a rigorous framework, this Thesis has significantly contributed to understanding the dynamics surrounding stakeholder responsiveness and acceptance within sustainable development. It has underscored the intricate interplay of diverse stakeholders, including government entities, businesses, local communities, and environmental organizations, in shaping the trajectory of sustainability initiatives.

The research has revealed the complexities of stakeholder engagement and the importance of effectively communicating and collaborating with these diverse groups. It has emphasized that sustainable development measures must be technically sound and culturally and socially relevant. Stakeholder perspectives are not just valuable insights; they are essential drivers of successful implementation.

Moreover, this research has provided a structured framework for evaluating stakeholder responsiveness and acceptance. By gauging stakeholders' attitudes, perceptions, and motivations, this framework allows for a systematic and data-driven assessment of the readiness and enthusiasm of different stakeholders in embracing sustainable development measures. It also identifies potential barriers and drivers for increased acceptance, which is invaluable for refining strategies and action plans.

In summary, this research not only contributes to the broader discourse on sustainable development but also equips decision-makers and advocates with valuable tools to enhance the responsiveness and acceptance of stakeholders. It reinforces the notion that sustainable development is a collaborative and dynamic process, highlighting the pivotal role of stakeholders in shaping a more sustainable, equitable, and prosperous future.

#### **9.1.e. Identifying the main indicators covering the vital critical aspects of port sustainability objectives**

This PhD Thesis has comprehensively explored the key indicators encapsulating the critical aspects of port sustainability objectives. Sustainable port management is paramount in today's globalized world, where ports are essential hubs of trade, economic activity, and environmental stewardship.

Identifying and effectively measuring the main indicators is a fundamental step toward assessing and improving the sustainability of these vital infrastructures. This Thesis has made significant contributions to our understanding of the multifaceted nature of port sustainability through a meticulous review of existing literature, empirical analysis, and the development of a robust framework. It has recognized the interconnected dimensions of sustainability, encompassing economic, environmental, social, and operational aspects, and the need for well-defined indicators to measure progress and performance.

The research has highlighted the importance of using indicators for port management and decision-making. Port authorities, policymakers, and stakeholders can gain insight into their progress toward sustainability objectives by defining and tracking key metrics. These indicators provide a means to assess trade-offs, set benchmarks, and guide the development of strategies that promote a balanced and integrated approach to sustainability.

Furthermore, this research has offered a structured framework for selecting and applying sustainability indicators. This framework empowers ports with the knowledge and guidance required to align their objectives with the broader sustainability agenda. By implementing a comprehensive set of indicators, ports can systematically measure their performance and take actionable steps toward sustainability, fostering transparency, accountability, and continuous improvement. Recognizing the importance of defining and measuring the main indicators is a practical necessity and a moral obligation in an era marked by the urgency of addressing environmental and social challenges.

#### **9.1.f Evaluating and comparing different ports based on applying best sustainable practices.**

Sustainable port management has become increasingly critical in the context of global trade and environmental concerns, demanding rigorous assessment and benchmarking of port performance to guide the adoption of sustainable practices. This PhD Thesis has embarked on a comprehensive journey to evaluate and compare various ports based on their application of best sustainable practices. It has recognized that the sustainability of ports involves diverse dimensions, including economic viability, environmental stewardship, social responsibility, and operational excellence. By evaluating and comparing these aspects, we can gain valuable insights into the current state of sustainable practices in the port industry.

The research has underscored the importance of these comparative assessments as essential tools for port stakeholders, including port authorities, policymakers, and industry players. It not only allows for the identification of strengths and weaknesses but also serves as a source of inspiration and knowledge sharing. By recognizing best practices in other ports, the industry can collectively

strive to raise the bar and implement solutions that enhance their sustainability performance. Furthermore, this research has provided a structured framework for evaluating and comparing ports based on sustainable practices. This framework ensures that the assessment process is consistent, comprehensive, and transparent. By applying this systematic approach, ports can objectively measure their sustainability achievements and areas that need improvement, ultimately guiding them toward a more sustainable and efficient future.

Expanding upon the implications of this research, it is crucial to recognize that as the world faces growing challenges related to climate change, resource depletion, and shifting global dynamics, the sustainability of ports takes on even greater significance. Ports are not isolated entities but critical components of a worldwide network, and their collective adoption of sustainable practices can have far-reaching impacts. By evaluating and comparing different ports, we encourage healthy competition and facilitate sharing knowledge and adopting innovations across the industry.

Moreover, the research findings emphasize the importance of collaboration between various stakeholders in the port community. It is not solely the responsibility of port authorities but also that of shipping companies, logistics providers, local communities, and government agencies to champion sustainable practices. The comparative evaluations showcased in this Thesis can catalyze dialogue and collaboration among these stakeholders, promoting a shared commitment to sustainability and collective efforts to achieve common goals. The evaluation and comparison of ports should be an ongoing process, reflective of the ever-changing sustainability landscape. Ports should remain open to continual improvement, innovation, and the incorporation of emerging best practices into their operations.

Furthermore, the Thesis highlights the significance of transparency and accountability in sustainable practices. When ports openly assess and compare their sustainability performance, they build trust and credibility with their stakeholders, from local communities to international trade partners. Transparent reporting and benchmarking can strengthen the social license to operate, attract investment, and enhance the overall reputation of the port, paving the way for long-term success.

In the broader context, this research's findings should not be viewed as a conclusion but as a starting point. Pursuing sustainable practices in the port industry is an ongoing journey. The knowledge and insights gained through these evaluations can serve as a foundation for future research, policy development, and industry initiatives to promote sustainability in ports.



### **9.1.g Identify and categorize threats prevalent among IoT devices in ports**

The comprehensive investigation into the security landscape of IoT devices in port environments has yielded significant insights into the prevalent threats faced by these interconnected systems. Through literature review and stakeholder interviews, this research has successfully identified a range of threats that pose risks to the integrity, confidentiality, and availability of IoT devices in the maritime environment. These threats encompass unauthorized access, data breaches, and physical tampering. The identification of these threats serves as a foundational contribution to the understanding of the security challenges surrounding IoT deployment in ports.

Building upon identifying threats, this research has established a robust categorization framework to systematically organize and classify the diverse range of risks IoT devices face within port infrastructures. The developed taxonomy considers each threat's unique characteristics and potential impact, providing a structured and comprehensive overview of the security landscape. This categorization not only aids in better understanding the nature of threats but also lays the groundwork for developing targeted and adequate security measures tailored to the specific challenges posed by different threats. The resulting taxonomy is a valuable tool for port operators, cybersecurity professionals, and policymakers seeking to enhance the resilience of IoT ecosystems in maritime environments.

Furthermore, the insights derived from this research have practical implications for developing proactive security strategies and risk mitigation measures. By understanding the specific threats in port IoT environments, stakeholders can implement targeted security protocols, access controls, and incident response plans to fortify the overall cybersecurity posture. The recommendations provided in this Thesis offer actionable guidance for port authorities, technology vendors, and cybersecurity experts to collaboratively address and mitigate the identified threats, fostering a more secure and resilient maritime infrastructure.

In conclusion, this PhD Thesis has successfully achieved its objective of identifying and categorizing threats prevalent among IoT devices in ports. The findings contribute not only to the academic understanding of cybersecurity challenges in maritime environments but also offer practical insights that can be applied to strengthen the security of IoT deployments in ports.

### **9.2 Future perspectives**

As we conclude this PhD Thesis on small and medium port sustainability planning, it is essential to outline future perspectives and potential directions for further research and practical applications in this dynamic field. This research's findings contribute significantly to understanding the challenges and opportunities associated with sustainable development in smaller port environments. The

following future perspectives highlight areas that warrant further exploration and potential advancements in the realm of small and medium port sustainability planning.

**a. Integration of Emerging Technologies**

Future research can delve into integrating emerging technologies, such as artificial intelligence and the Internet of Things, to enhance the efficiency and sustainability of small and medium ports. Investigating how these technologies can optimize logistics, reduce energy consumption, and improve environmental monitoring would be instrumental in shaping the next generation of sustainable port operations.

**b. Resilience in the Face of Climate Change**

As climate change continues to pose challenges to coastal areas, future studies should focus on enhancing the resilience of small and medium ports. This includes evaluating strategies for adapting to rising sea levels, extreme weather events, and changing environmental conditions. Sustainable planning should incorporate robust measures to mitigate the impact of climate-related disruptions on port activities.

**c. Community Engagement and Social Sustainability**

Expanding research to understand the social aspects of sustainability in smaller ports is crucial. Investigating how community engagement and social considerations influence sustainability planning will provide a more holistic understanding. This involves exploring the socio-economic impacts of port activities on local communities and developing strategies that foster positive relationships between ports and their surrounding areas.

**d. Policy and Regulatory Frameworks**

Examining the effectiveness of existing policies and regulatory frameworks in promoting sustainability within small and medium ports is vital. Future research could focus on proposing and evaluating new policies or refining existing ones to create an enabling environment for sustainable practices. Comparative studies between regions and countries can provide valuable insights into best practices and regulatory innovations.

**e. Capacity Building and Knowledge Transfer**

To ensure the successful implementation of sustainability initiatives, future efforts should be directed towards capacity building within smaller port communities. This includes training

programs, knowledge transfer initiatives, and collaborative platforms that facilitate the exchange of best practices and lessons learned in sustainable port planning.

**f. Circular Economy Approaches**

Investigating and promoting circular economy principles within small and medium ports can be a promising avenue for future research. This involves exploring ways to minimize waste, optimize resource utilization, and create closed-loop systems that contribute to the overall sustainability of port operations.

**g. Global Collaboration and Information Sharing**

Small and medium ports often face similar sustainability challenges worldwide. Facilitating global collaboration and information-sharing platforms can enhance the exchange of knowledge, experiences, and innovative solutions. International partnerships and networks can be pivotal in promoting sustainable practices and fostering a collective approach to address common challenges. In conclusion, the future perspectives outlined above provide a roadmap for researchers, policymakers, and industry stakeholders to continue advancing the field of small and medium port sustainability planning. Embracing these future directions will contribute to developing more resilient, efficient, and environmentally conscious port operations in the coming years.

### **9.3 Limitations**

Despite the thorough investigation and valuable insights gained through this PhD Thesis on small and medium port sustainability planning, it is crucial to acknowledge the inherent limitations of the research. Recognizing these limitations is essential for a nuanced understanding of the scope and applicability of the findings, and it sets the stage for future research endeavors. The following are some critical limitations associated with this study:

**a. Generalization Challenges**

The research focused on specific small and medium ports, and while efforts were made to select diverse case studies, the findings may only be partially generalizable to some small and medium ports worldwide. Each port has unique geographical, economic, and contextual factors that can influence the applicability of sustainability planning strategies.

**b. Temporal Constraints**

The dynamic nature of sustainability challenges and the evolving nature of port operations pose a challenge regarding the temporal relevance of the findings. The data collected and analyzed for this Thesis represent a specific time frame, and changes in technology, regulations, or economic conditions over time may impact the validity of certain recommendations.

**c. Data Availability and Quality**

Data quality and availability can impact the depth and breadth of the research findings. Small and medium ports may only sometimes have comprehensive and up-to-date data on various sustainability metrics. This limitation can affect the precision of the analysis and the ability to draw robust conclusions.

**d. Limited Stakeholder Perspectives**

While efforts were made to incorporate various stakeholder perspectives, including port authorities, local communities, and environmental groups, the study may need to fully represent the diversity of opinions and interests within these groups. Different stakeholders in the sample may have distinct priorities and concerns that need to be fully explored in this research.

**e. Economic Considerations**

The economic aspects of sustainability planning, such as the cost-effectiveness of specific measures, were touched upon but not extensively explored. Future research could delve deeper into the economic implications of sustainability strategies, including cost-benefit analyses and financial feasibility studies.

**f. Limited Exploration of Emerging Technologies**

The study briefly touched upon the potential role of emerging technologies in sustainability planning. However, the rapidly evolving nature of technology and its integration into port operations warrants more in-depth exploration, which was beyond the scope of this Thesis.

Despite these limitations, this research's findings provide a valuable foundation for understanding the complexities of sustainability planning in small and medium ports. Future studies can build upon these insights, addressing the identified limitations to contribute further to advancing sustainable practices in the maritime industry.

## Appendix A

**Table A1** Aggregate weights of main and sub-indicators for all experts (CHA-port)

Main Indicators	Weights of Main Indicators	Sub Indicators	Weights of Sub-Indicators	Global Weights	Ranking
GI	0.033	GI 1	0.12	0.004	40
		GI 2	0.288	0.01	30
		GI 3	0.128	0.004	39
		GI 4	0.176	0.005	36
		GI 5	0.288	0.01	29
EMM	0.331	EMM 1	0.08	0.026	14
		EMM 2	0.158	0.052	4
		EMM 3	0.136	0.045	6
		EMM 4	0.41	0.136	1
		EMM 5	0.216	0.072	3
ME	0.1	ME 1	0.188	0.019	17
		ME 2	0.41	0.041	7
		ME 3	0.18	0.018	19
		ME 4	0.11	0.011	27
		ME 5	0.112	0.011	26
TE	0.067	TE 1	0.128	0.009	32
		TE 2	0.208	0.014	23
		TE 3	0.174	0.012	25
		TE 4	0.08	0.005	38
		TE 5	0.41	0.027	12
WM&R	0.08	WM&R 1	0.096	0.008	34
		WM&R 2	0.186	0.015	22
		WM&R 3	0.18	0.014	24
		WM&R 4	0.128	0.01	31
		WM&R 5	0.41	0.033	11
EET	0.133	EET 1	0.338	0.045	5
		EET 2	0.16	0.021	15
		EET 3	0.12	0.016	21
		EET 4	0.08	0.011	28
		EET 5	0.302	0.04	8
SE&SP	0.2	SE&SP 1	0.188	0.037	9
		SE&SP 2	0.136	0.027	13
		SE&SP 3	0.088	0.018	18
		SE&SP 4	0.41	0.082	2
		SE&SP 5	0.178	0.036	10
CMS	0.056	CMS 1	0.338	0.019	16
		CMS 2	0.12	0.007	35
		CMS 3	0.302	0.017	20
		CMS 4	0.096	0.005	37
		CMS 5	0.144	0.008	33

**Table A2** Aggregate weights of main and sub-indicators for all experts (RET-port)

Main Indicators	Weights of Main Indicators	Sub Indicators	Weights of Sub-Indicators	Global Weights	Ranking
GI	0.033	GI 1	0.324	0.011	25
		GI 2	0.252	0.008	33
		GI 3	0.096	0.003	40
		GI 4	0.136	0.005	38
		GI 5	0.192	0.006	34
EMM	0.2	EMM 1	0.23	0.046	6
		EMM 2	0.12	0.024	15
		EMM 3	0.112	0.022	18
		EMM 4	0.41	0.082	2
		EMM 5	0.128	0.026	13
ME	0.067	ME 1	0.166	0.011	26
		ME 2	0.338	0.023	16
		ME 3	0.138	0.009	32
		ME 4	0.08	0.005	39
		ME 5	0.28	0.019	21
TE	0.1	ANC 1	0.112	0.011	27
		ANC 2	0.252	0.025	14
		ANC 3	0.266	0.027	12
		ANC 4	0.096	0.01	29
		ANC 5	0.274	0.027	11
WM&R	0.056	WM&R 1	0.112	0.006	35
		WM&R 2	0.15	0.009	31
		WM&R 3	0.252	0.014	23
		WM&R 4	0.112	0.006	36
		WM&R 5	0.374	0.021	19
EET	0.08	EET 1	0.08	0.006	37
		EET 2	0.12	0.01	28
		EET 3	0.174	0.014	24
		EET 4	0.266	0.021	20
		EET 5	0.36	0.029	10
SE&SP	0.133	SE&SP 1	0.374	0.05	5
		SE&SP 2	0.174	0.023	17
		SE&SP 3	0.142	0.019	22
		SE&SP 4	0.23	0.031	9
		SE&SP 5	0.08	0.01	30
CMS	0.331	CMS 1	0.41	0.136	1
		CMS 2	0.216	0.071	3
		CMS 3	0.104	0.034	8
		CMS 4	0.112	0.037	7
		CMS 5	0.158	0.053	4

**Table A3** Aggregate weights of main and sub-indicators for all experts (SIT-port)

Main	Weights of Main	Sub	Weights of Sub-	Global Weights	Ranking
GI	0.033	GI 1	0.288	0.009	33
		GI 2	0.338	0.011	25
		GI 3	0.08	0.003	40
		GI 4	0.12	0.004	39
		GI 5	0.174	0.006	26
EMM	0.2	EMM 1	0.238	0.048	6
		EMM 2	0.142	0.028	12
		EMM 3	0.08	0.016	21
		EMM 4	0.374	0.075	3
		EMM 5	0.166	0.033	8
ME	0.067	ME 1	0.18	0.012	23
		ME 2	0.41	0.027	13
		ME 3	0.172	0.012	24
		ME 4	0.08	0.005	38
		ME 5	0.158	0.011	27
TE	0.1	TE 1	0.104	0.011	30
		TE 2	0.252	0.025	15
		TE 3	0.294	0.029	10
		TE 4	0.112	0.011	29
		TE 5	0.238	0.024	17
WM&R	0.056	WM&R 1	0.088	0.005	37
		WM&R 2	0.142	0.008	35
		WM&R 3	0.202	0.011	26
		WM&R 4	0.158	0.023	34
		WM&R 5	0.41	0.056	18
EET	0.133	EET 1	0.374	0.05	5
		EET 2	0.238	0.031	9
		EET 3	0.12	0.016	20
		EET 4	0.08	0.011	31
		EET 5	0.188	0.025	16
SE&SP	0.08	SE&SP 1	0.18	0.015	22
		SE&SP 2	0.128	0.01	32
		SE&SP 3	0.228	0.018	19
		SE&SP 4	0.324	0.026	14
		SE&SP 5	0.14	0.011	28
CMS	0.331	CMS 1	0.374	0.124	1
		CMS 2	0.088	0.029	11
		CMS 3	0.128	0.042	7
		CMS 4	0.23	0.076	2
		CMS 5	0.18	0.06	4

## Appendix B.

Table B1: Terrorism															
Mean	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM
1	2	2	4	3	3	9	2	2	4	3	3	9	3	2	6
2	3	3	9	3	4	12	2	2	4	3	3	9	3	2	6
3	1	3	3	3	3	9	1	2	2	3	3	9	2	2	4
4	3	3	9	4	3	12	2	2	4	3	3	9	3	4	12
5	1	3	3	3	4	12	1	2	2	2	3	6	2	2	4
6	2	3	6	3	3	9	2	2	4	3	3	9	3	4	12
7	1	3	3	3	4	12	1	2	2	2	4	8	2	3	6
8	1	2	2	3	4	12	2	2	4	3	3	9	4	2	8
9	2	2	4	3	3	9	3	2	6	2	4	8	2	4	8
10	1	2	2	3	3	9	3	3	9	3	3	9	3	3	9
11	2	2	4	4	3	12	2	2	4	3	3	9	2	2	4
12	2	2	4	2	4	8	1	2	2	2	2	4	2	2	4
13	2	2	4	3	3	9	2	2	4	3	3	9	3	2	6
14	1	3	3	3	4	12	2	3	6	3	4	12	3	3	9
15	2	2	4	2	5	10	3	2	6	2	4	8	2	2	4
16	1	2	2	3	4	12	1	2	2	2	4	8	3	3	9
17	2	3	6	2	4	8	2	2	4	3	4	12	4	2	8
18	1	3	3	2	3	6	1	3	3	3	4	12	3	2	6
Sum	30	45	75	52	64	182	33	39	72	48	60	159	49	46	125
AV	1.6	2.5	4.2	2.9	3.6	10.1	1.8	2.2	4	2.7	3.3	8.8	2.7	2.6	6.9
Event	TE1			TE2			TE3			TE4			TE5		

Table B2: Pandemic									
Mean	P	S	ORM	P	S	ORM	P	S	ORM
1	5	3	15	3	3	9	4	4	16
2	3	3	9	4	4	16	4	3	12
3	2	2	4	3	3	9	3	3	9
4	3	2	6	3	2	6	3	3	9
5	3	3	9	4	4	16	3	3	9
6	4	3	12	4	4	16	4	3	12
7	4	3	12	5	4	20	3	3	9
8	4	3	12	3	4	12	3	2	6
9	5	3	15	5	3	15	4	3	12
10	3	2	6	4	3	12	3	3	9
11	4	3	12	4	3	12	4	4	16
12	3	3	9	3	4	12	4	3	12
13	4	4	16	4	4	16	4	3	12
14	5	3	15	4	3	12	4	3	12
Mean	P	S	ORM	P	S	ORM	P	S	ORM
15	4	4	16	3	4	12	3	4	12
16	5	3	15	4	3	12	3	4	12
17	4	3	12	3	4	12	4	4	16
18	5	3	15	4	4	16	3	4	12
Sum	70	53	210	67	63	235	63	59	207
AV	3.9	2.9	11.7	3.7	3.5	13.1	3.5	3.3	11.5
Event	PE1			PE2			PE3		



Table B3: Human effect						
Mean	P	S	ORM	P	S	ORM
1	3	3	9	3	4	12
2	3	3	9	2	3	6
3	3	2	6	1	4	4
4	2	3	6	2	3	6
5	3	2	6	2	3	6
6	3	3	9	3	3	9
7	3	2	6	3	3	9
8	3	3	9	3	3	9
9	3	3	9	1	4	4
10	2	3	6	2	2	4
11	2	3	6	4	3	12
12	3	3	9	2	3	6
13	2	3	6	2	4	8
14	3	3	9	3	4	12
15	3	3	9	2	4	8
16	3	3	9	2	3	6
17	3	3	9	3	4	12
18	3	3	9	2	3	6
Sum	50	51	141	43	60	143
AV	2.8	2.8	7.8	2.4	3.3	7.9
Event	HE1			HE2		

Table B4: Cybersecurity									
Mean	P	S	ORM	P	S	ORM	P	S	ORM
1	2	4	8	2	3	6	4	4	16
2	4	3	12	4	3	12	4	3	12
3	3	3	9	3	4	12	4	4	16
4	2	4	8	2	2	4	3	3	9
5	2	4	8	2	2	4	3	3	9
6	4	3	12	3	3	9	3	3	9
7	4	4	16	4	4	16	4	4	16
8	3	4	12	3	3	9	3	3	9
9	3	4	12	4	4	16	3	4	12
10	2	4	8	2	3	6	2	2	4
11	2	3	6	3	3	9	4	3	12
12	3	3	9	3	4	12	4	3	12
13	3	4	12	3	4	12	4	4	16
14	3	4	12	4	4	16	4	4	16
15	3	3	9	4	4	16	3	4	12
16	3	4	12	3	4	12	4	4	16
17	3	3	9	4	4	16	4	4	16
18	3	4	12	3	3	9	3	4	12
Sum	52	65	186	58	63	208	62	63	221
AV	2.9	3.6	10.3	3.2	3.5	11.6	3.4	3.5	12.3
Event	CE 1			CE 2			CE 3		

Table B5: Maintenance															
Mean	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM
1	2	2	4	2	2	4	3	2	6	2	2	4	2	2	4
2	2	2	4	1	2	2	2	2	4	1	3	3	2	2	4
3	2	3	6	1	2	2	1	4	4	1	3	3	1	2	2
4	3	3	9	2	1	2	3	3	9	3	3	9	2	3	6
5	4	2	8	2	2	4	3	3	9	2	2	4	1	2	2
6	3	4	12	2	3	6	4	4	16	4	2	8	3	2	6
7	2	4	8	2	2	4	3	4	12	3	4	12	3	3	9
8	3	2	6	2	2	4	4	3	12	4	2	8	2	2	4
9	3	4	12	2	4	8	2	4	8	4	3	15	3	2	6
10	3	2	6	1	1	1	2	2	4	2	2	4	2	2	4
11	3	3	9	2	2	4	4	3	12	2	3	6	3	3	9
12	2	1	2	2	1	2	1	2	2	3	3	9	2	3	6
13	3	4	12	2	2	4	2	3	6	3	2	6	2	3	6
14	2	4	8	2	2	4	3	4	12	3	2	6	3	2	6
15	3	3	9	1	2	2	2	3	6	3	3	9	3	2	6
16	3	3	9	2	3	6	3	3	9	2	3	6	2	3	6
17	2	4	8	1	2	2	3	3	9	3	3	9	2	3	6
18	3	4	12	1	3	3	2	3	6	3	2	6	3	2	6
Sum	48	54	144	30	38	64	47	55	146	48	47	124	41	43	98
AV	2.7	3	8	1.7	2.1	3.6	2.6	3.1	8.1	2.7	2.6	6.9	2.3	2.4	5.4
Event	ME 1			ME 2			ME 3			ME 4			ME 5		

Table B6: Natural disasters																							
Mean	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM	P	S	ORM		
1	2	2	4	2	2	4	4	2	8	2	2	4	2	2	4	2	2	4	2	3	6		
2	2	1	2	1	1	1	3	1	3	3	2	6	2	2	4	1	2	2	2	2	4		
3	2	1	2	1	1	1	2	2	4	3	2	6	1	3	3	1	3	3	1	2	2		
4	3	1	3	1	1	1	3	1	3	2	2	4	2	2	4	1	2	2	2	2	4		
5	2	2	4	2	2	4	2	1	2	2	2	4	2	3	6	1	3	3	1	2	2		
6	3	3	9	2	2	4	2	2	4	2	2	4	2	2	4	2	2	4	3	3	9		
7	4	2	8	2	1	2	3	1	3	2	2	4	2	2	4	1	2	2	3	2	6		
8	2	3	6	1	1	1	2	2	4	3	2	6	1	2	2	1	3	3	3	3	9		
9	2	3	6	2	2	4	2	3	6	3	3	9	2	3	6	3	3	9	4	3	12		
10	3	3	9	3	3	9	2	1	2	2	1	2	2	2	4	2	2	4	2	3	6		
11	3	3	9	3	2	6	3	3	9	2	2	4	1	3	3	1	2	2	2	3	6		
12	2	3	6	1	1	1	3	1	3	2	2	4	1	3	3	2	2	4	2	1	2		
13	3	2	6	2	2	4	4	2	8	3	2	6	2	3	6	1	2	2	3	2	6		
14	2	2	4	3	1	3	2	3	6	3	1	3	2	3	6	1	3	3	4	2	8		
15	2	3	6	3	1	3	3	2	6	2	2	4	2	3	6	2	2	4	4	3	12		
16	3	3	9	2	2	4	3	2	6	2	2	4	2	3	6	1	2	2	4	2	8		
17	3	1	3	2	2	4	3	2	6	3	2	6	2	3	6	2	2	4	3	3	9		
18	2	2	4	3	2	6	2	3	6	3	2	6	2	3	6	2	2	4	4	2	8		
Sum	45	40	100	36	29	62	48	34	89	44	35	86	32	47	83	27	41	61	49	43	119		
AV	2.5	2.2	5.6	2	1.6	3.4	2.7	1.9	4.9	2.4	1.9	4.8	1.8	2.6	4.6	1.5	2.3	3.4	2.7	2.4	6.6		
Event	ND1			ND2			ND3			ND4			ND5			ND6			ND7				

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