Article

Port Greening: Discrete Choice Analysis Investigation on Environmental Parameters Affecting Container Shipping Companies' Behaviors

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Abstract: For centuries, ports have functioned as an economic engine, facilitating maritime transport, offering prosperity and social development to the host communities. Ports are gateways for international trade playing a vital role in the world economy, but it is not excluded that port operations can also have adverse effects on the environment. Air and water emissions, marine sediments, noise, waste generation, loss and degradation of terrestrial habitats and changes to marine ecosystems are just some of the leading environmental challenges with port's operations. Environmental management within port operations has been a rapidly growing trend, with many ports around the world adopting different types of approaches and initiatives to improve ecological performance. Despite that many ports around the world have implemented greening strategies for growth and sustainable development, there are still many other ports that work less than they should do on environmental aspects and on the generation of '*green ports*'. These latter have fallen behind in the development of the theme. Therefore, the work reported here aims at analyzing what the best way to act should be, even starting from the beginning for a port that is not very innovative, in order to pursue the practical and theoretical levels of '*green port*'.

Keywords: green ports; shipping companies; ecology; discrete choice analysis

1. Introduction to Sustainability and Green Port Concept

Sustainability within maritime transport is linked to the notion of ensuring safe, efficient and reliable transport of goods, minimizing the effects on the environment and maximizing resource efficiency. The sustainability of the port indicates the port strategies and activities that meet the current and future needs of the ports and their stakeholders, protecting and supporting human and natural resources. Research has defined a green port as a product of a long-term strategy for the sustainable development of the port infrastructure, with attention to minimizing greenhouse gas (GHG) emissions, [1]. This publication also suggests that green ports work to balance economic demand with environmental responsibility through research and innovation because the concept of sustainability considers social, economic and environmental issues.

The concept of the green port is more restricted than the concept of sustainable development. The most common definition of sustainable development is: "*development that meets the needs of the present without compromising the ability of future generations to meet their needs*" (Brundtland Report 1987 entitled "Our Common Future" published by the United Nations World Commission on Environment and Development) [2]. Therefore, it is also possible to speak of sustainable development in the port sector when principles coexist that take into account current and future needs dedicated to maritime transport. The maritime industry has been seen as significant support for economic development

over the past 300 years, and the introduction of containerization has significantly altered the connections between players in the freight transport chain. Consequently, ports around the world are now growing at an exceptional rate, and their performance considers not only their production and efficiency, but also their ecological performance. Many ports around the world have pledged to be a sustainable port and have adopted green port strategies. The adoption of green initiatives allows ports to establish their commitments and responsibilities towards the environment and society. Ports that invest in improving environmental performance have three potential reasons behind. These are:

- Obtaining or improving their social license to operate;
- Improving their corporate conscience;
- Increasing their competitive advantage (cost reduction, efficiency, etc.).

Most of these initiatives allowed observing that the adoption of environmental management programs and ecologic commercial strategies bring better environmental performance and substantial competitiveness. Value-added services for environmental management can bring many benefits to port cities. Value-added services (e.g., industrial development, coastal development and port facilities) and port activities have influencing impacts on job creation and income, on port services and supply of goods; all together they bring productivity, growth and economic attractiveness for ports.

Ports have been seen as platforms for the circulation and conversion of material and energy flows, and as such, they can be seen as interesting laboratories for the implementation of the 'industrial ecology' concept. Industrial ecology refers to the optimization of resource consumption and the correct management of by-products (waste) through the intensification of interactions between the various stakeholders who are in a common geographical area [3].

There are numerous challenges to be faced when undertaking the initiative to become a green or sustainable port. The environmental, economic and social challenges that ports encounter include the increase in maritime traffic volumes, the increasing size of ships, the cost of upgrading port capacity, the volatile energy prices, the transition to alternative fuels and stricter limits on sulphur emissions principally. The latter are stimulated strongly and even imposed by the IMO regulations.

In addition, the impact on maritime operators also needs to be considered. Indeed, in parallel to the heavy challenges, there is even increasing pressure from shippers, who demand green supply chains, over and above any international regulations. There is also port state control and local port fines given in case of non-compliance with local regulations. The latter concerns very often noise pollution.

Moreover, ports must face three main challenges to try to implement environmental management. These are:

- Search for interested parties/competent authorities involved;
- Lack of knowledge in the implementation of sound environmental management practices;
- The cost of environmental management measures;

In this research, it is considered that green ports should be based on the balance between environmental impact and economic interests, as well as embodying the concept of sustainability. Economic and environmental benefits that should be considered are the following:

- Not consider the environment as spending;
- Pay attention to environmental protection and eco-compatible development;
- Save resources and energy in the development process;
- Strengthen environmental management;
- Build ecologically civilized ports;
- Accelerate sustainable development of the harmonious natural-economic-social model.

Following up on the above practical considerations, the primary and most profound ethical element that characterizes the construction of a green port is the harmony between

man and nature. The inclusion of good environmental quality, economical and efficient resources, good ecological at tributes and healthy environmental management are economic efficiency, social civilization, sustainable port development and ecological port development. The construction of green ports should be included in port construction and coastal development planning and taken as part of port planning.

By applying the notion of building green ports in port planning, reasonable port development policies can be proposed from the environment and resources point of view, which can facilitate the distribution of productive forces and the rationalization of the industrial structure. This can be done starting from the concept of pollution prevention and control for the entire duration of the port planning process, then combining these control measures with technological innovation, with the reform and renewal of the equipment, with production efficiency obtaining the coordination of the environment and the economic development of the port.

This paper will investigate where the primary needs for green port development lie, given the preferences of port users. It will do so by applying a discrete choice survey and analysis to a representative sample of global container shipping companies. This should allow visualizing which green elements play the biggest role in these operators' port choice decision making.

The intent of this paper is to make a contribution in two areas, primarily the academic and the working sectors of the maritime environment. In terms of academic perspective, this paper is able to demonstrate an accurate understanding of container terminal management explaining on which aspects to intervene based on the results obtained. A second aim of this paper is to guide and sensitize those who work in the sector with regard to the problems that arise and develop in relation to port ecology.

Research interest in the development of the green and sustainable port concept has always evolved around the fundamental requirement of a consistent reduction of negative environmental impacts in all their forms [1,4,5].

Today, ports need to improve their performance in this area, and therefore are constantly working on more environmentally sustainable and efficient behaviors, investing a significant number of resources [2,3]. This helps, first of all, not to compromise economic growth, and secondly, provides a starting point for defining and then applying new managerial tools able to assess, monitor and measure the effects of the green choices made by the responsible entities [4–6].

The new increasingly environmentally sustainable behaviors implemented by seaports lead to reflect on a fundamental point for this research: The growth of port competitiveness from an ecological/environmental point of view, which deeply influences the effectiveness and efficiency of the decision-making processes of maritime companies.

This article will therefore investigate the attractiveness of a seaport from a green point of view, and thus, more detail on how and how much the environmental parameters of such a port affect the berthing choice processes of shipping companies. Our research question is which environmental factors (managerial and monitoring factors) are most effective in influencing the decision-making processes and the subsequent decisions of a container shipping company? Furthermore, what are, therefore, the selection criteria that these companies use to satisfy their logistical interests? The next section details the method and the concrete model applied. Section 3 prepares the experimental design. Section 4 sets up the experiment. Section 5 presents the results. Finally, Section 6 draws conclusions.

2. Methodology and Model Used

Pursuing environmental strategies that lead to the creation of a green port is the basis for solving of ecological problems in the world of maritime transport. The work that has been done through the years has been to continually and innovatively research the various criteria and attributes that most influence the concept of green ports.

To date, there seem to be multiple criteria of influence (which govern the concept of port greening). It is therefore why, for the first time, this research, through an operational

phase of Discrete Choice Analysis (DCA), aims to analyze the most important of these criteria and to highlight the key ones for a container shipping company when deciding its approach to a port.

A discrete choice experiment makes it possible to attribute an importance value (for the most of economic importance) to each of the evaluation and definition criteria of the phenomenon studied so that they can be compared with each other and their importance, setting priorities [7].

Once the importance of these criteria has been established, it is possible to proceed with the appropriate actions, and measures to improve them in every aspect. In order to define the discrete choice analysis, it is essential to determine what the alternatives would be in the survey (in the form of a questionnaire) that will be conducted to highlight the criteria mentioned before. The topic will be addressed with more accuracy in the dedicated section.

The alternatives that were taken into consideration in this Discrete Choice Analysis were two generic ports (Port A and Port B) in which any container shipping company could dock.

In order to better understand the steps of the followed approach, Figure 1 reports a flow chart that collects the necessary phases for the development of the discrete choice analysis.
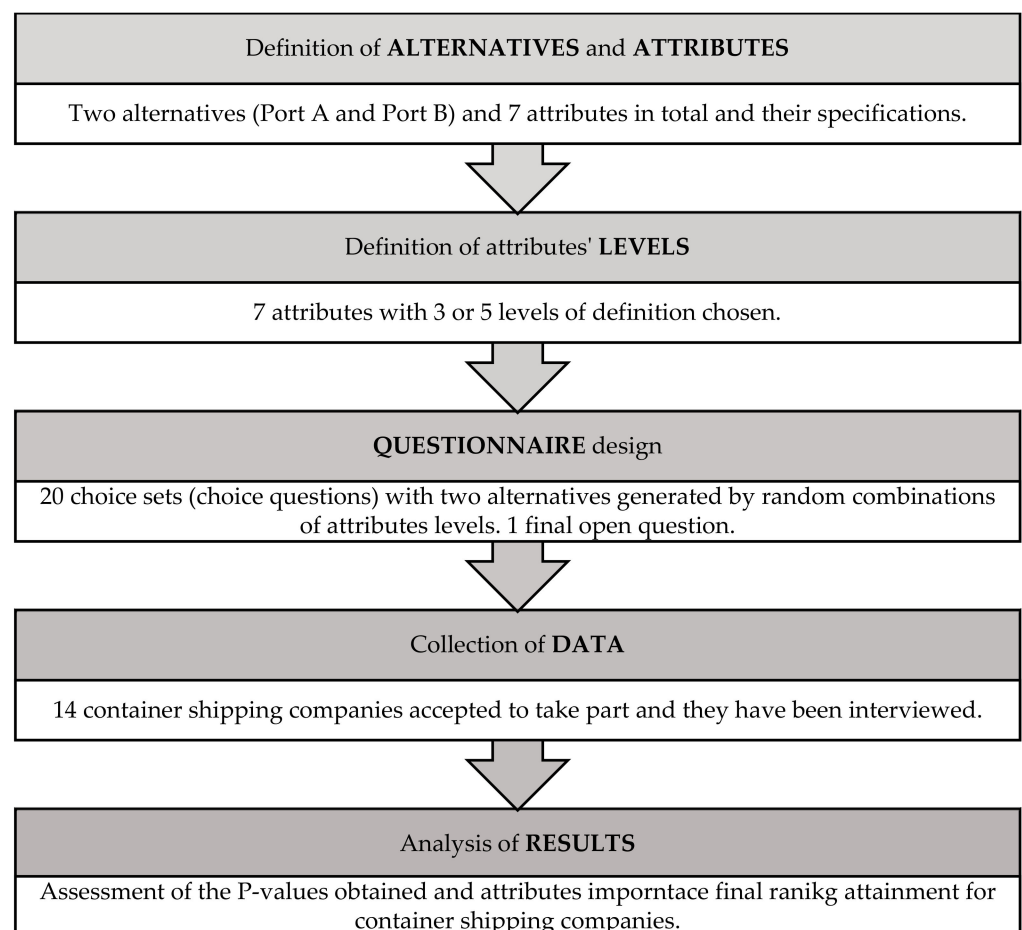

| Definition of **ALTERNATIVES** and **ATTRIBUTES** |
| Two alternatives (Port A and Port B) and 7 attributes in total and their specifications. |

| Definition of attributes' **LEVELS** |
| 7 attributes with 3 or 5 levels of definition chosen. |

| **QUESTIONNAIRE** design |
| 20 choice sets (choice questions) with two alternatives generated by random combinations of attributes levels. 1 final open question. |

| Collection of **DATA** |
| 14 container shipping companies accepted to take part and they have been interviewed. |

| Analysis of **RESULTS** |
| Assessment of the P-values obtained and attributes imporntace final ranikg attainment for container shipping companies. |

Figure 1. Phases of the analysis development. Source: Own composition.

2.1. Discrete Choice Analysis Methodology (DCA)

The theory of discrete choice analysis is based on the behavior of choice by the respondent, where the behavioral process in making choices is central. Furthermore, the theory of discrete choice analysis is based on the theory of "*random utility*", which states

that not all the attributes that are added to the general utility of a good or service can be observed by the analyst.

Therefore, a product or service overall utility can be perceived and therefore written as a composition of observed attributes and unobserved utility sources. This is explained by Equation (1) in which the utility associated with the choice of the *j-th* product/service is defined, among the many alternatives available, relative to the *i-th* consumer:

$$U_{ij} = V_{ij} + \epsilon_{ij} \tag{1}$$

where:

- U_{ij} represents the latent utility that the nth consumer attributes to the *i-th* alternative product selected;
- V_{ij} represents that portion of directly observable utility, also called deterministic, systemic or representative, determined by the individual characteristics of the *n-th* consumer as well as by the characteristics of the attributes of the *i-th* selected good/service;
- ϵ_{ij} represents the part of stochastic utility that cannot be directly explained by the researcher. The presence of the stochastic error implies that the real utility, from the researcher's point of view, remains unobservable.

All this is based on the so-called "*Consumer Theory*", according to which it is possible to break down the usefulness of a given product/service into many utilities related to the individual characteristics or attributes of the product/service itself and on the "*Random Utility Theory*".

2.2. The Model

Discrete choice models are disaggregated demand models, which model discrete choices. The individual or respondent chooses from a finite number of alternatives. In general, "*the probability that individuals choose a particular alternative is a function of their socioeconomic characteristics and the relative attractiveness (utility) of the alternative*" [7]. Therefore, any individual or any respondent:

- Knows all the alternatives available as a whole of choice;
- Evaluates each alternative based on its characteristics;
- Associates with each alternative a level of satisfaction that is measured through an index of utility;
- Confirms the alternatives on the basis of the level of satisfaction received and always chooses the most attractive alternative, that is the one that gives greater satisfaction.

Two viewpoints can be observed in a model of this type. The first viewpoint concerns that of the individual and the second one that of the modeler. The individual has a perfect knowledge of the landscape that is being judged and always chooses the alternative that offers the maximum utility (i.e., perfect behavioral theory), keeping in mind that the preferences of individuals are always consistent and transitive, i.e., they do not always show rational behavior. On the other hand, the modeler shows a point of view of an element that has absolutely no perfect information and therefore assumes that the usefulness of the alternative made available is defined by two components:

- A systematic component (a function of measured attributes);
- A random part that contains the errors committed by the same modeler and the latent aspects that underlie the choice (inertia, habit, aversion, etc.).

Multinomial Logit Model (MNL)

One of the simplest and most common discrete choice models is the multinomial logit (MNL) model that was first introduced by McFadden in 1974 [7]. In this model, the relative utility of an alternative in a choice situation can be written as follows in Equation (2):

$$U_{jsn} = x'_{jsn}\beta + \varepsilon_{jsn} \tag{2}$$

where:

- U_{jsn} is the utility that a respondent n attributes to alternative j in situations of choice s;
- x_{jsn}' is k x 1 vector containing the alternative attribute levels j in the choice set s for the respondent n;
- β is k x 1 vector of parametric values (part-worths);
- ε_{jsn} is the Gumbel error term, which incorporates the unobserved sources of utility.
- Given the random utility model, under the assumption that the error terms are independently and identically Gumbel distributed, the MNL probability (p_{jsn}) that a respondent n chooses the profile j in the sets of choice s as Equation (3) demonstrates, is:

$$p_{jsn} = \frac{\exp\left(x_{jsn}'\beta\right)}{\sum_{t=1}^{j} \exp(x_{tsn}'\beta)} \tag{3}$$

However, the MNL shows some shortcomings, of which the three most significant are: (1) its inability to account for taste heterogeneity between respondents; (2) its inability to account for the fact that respondents usually answer multiple-choice questions and therefore, correlations might be introduced; and (3) it assumes that the unobserved components of the utility are independent and identically distributed [8]. To go in depth on this third point, it has to be understood that the unobserved components of the utility function have to be independent and identically distributed.

Furthermore, the ratio between the probabilities of two alternatives has to be independent of the presence of additional alternatives (independent from irrelevant alternatives). Therefore, when adding a third alternative to a set of two alternatives, this should not affect the ratio of the probability of the two other alternatives.

3. Experimental Design: Definition of Alternative

This section prepares the experimental design for the analysis in the next sections, by defining alternatives and attributes.

3.1. Alternatives

Before carrying out the research, a clarification has to be made concerning the alternatives of the experiment. In general, it is necessary to define every possible alternative to make the experiment as realistic as possible. However, very often, the alternatives can be numerous, and so not all of them can be included in the experiment, but it is necessary to reduce their number. The first option is to work with unlabeled alternatives in which the alternatives are not defined by their real name but only by their attributes and attribute levels [8]. The other option is to work with labeled alternatives in which the attribute levels do not vary as much as in the unlabeled experiment if the choices are kept as realistic as possible. In this study, it was decided to work with the unlabeled alternative (i.e., without giving a specific name to the alternatives), so as to obtain a definition of the alternatives based on the variation of the levels of the attributes that define them. However, in this case, this tactic was not used to limit the alternatives but rather to generalize them.

In this way, it was possible to play with various combinations of variations of attributes, and this has ensured the study carried out was more casual and probabilistic. The search for the attributes and the levels that define them was fundamental to be able to then define the alternatives, and it was decided to reduce them, as specified before, to only two elements. So, in this research, a discrete analysis study based on the use of two distinct alternatives was used, characterized by different attribute levels. Later, as will be seen, we will talk about alternative A (Port A) and alternative B (Port B).

3.2. Attributes

A second step in specifying the model is the identification of the attributes (often also referred to as factors or indicators) of the choice of the port and their levels to be used in

the discrete choice analysis, obtained by detailed research of Port Sustainability Indicators (PSI).

An Environmental Performance Indicator (EPI) is defined as an "information tool that summarizes data on complex environmental issues to show the general state and trends of these issues" [4].

These attributes are increasingly developed and used as management tools to address environmental issues. The use of attributes in environmental issues is strongly recommended due to several reasons, namely to:

- Monitor progress and provide an overview of trends and changes over time;
- Provide simplified data that not only clearly shows the performance of an individual authority, but also evaluates the national and regional reference performances of the sector;
- Assess the effectiveness of implemented policies, measuring progress towards environmental objectives and providing a reference basis for future objectives.
- Have a key role in providing early warning information, which can serve as a signal if the situation worsens, indicating the risk before severe damage occurs;
- Can be used as a powerful tool to raise public awareness of environmental issues.

Within the port sector, potential users of environmental attributes include workers of the port authority, companies and industries that invest in the port (such as terminal operators or maritime agencies), political decision-makers and civil society organizations.

The development and selection of environmental attributes have become a relatively complex process due to their multifunctional nature. For example, they are expected to reflect a wide range of environmental problems, show trends over time, anticipate changes and influence management decisions. Consequently, the selection of environmental attributes should be accompanied by a rigorous validation process.

Although several methods for selecting attributes have been suggested, according to [5,6], there are two main approaches to selecting attributes: Top-down and bottom-up. The top-down approach is based on the identification of attributes from the literature review (e.g., publications, reports and standards) and the restriction to a final set of agreed attributes. The bottom-up approach consists of compiling the final set of attributes from the proposals of sector stakeholders based on their perception of the problems and meanings. The methodology performed in this research combines both methods a little, relying mainly on a top-down approach.

For this research, it was possible to create a grouping of a series of port greening attributes, defined as port sustainability attributes. Initially, a number of attributes exceeding fifteen was found and selected from an extensive literature review [9–23].

For the study addressed here, it is not appropriate to have an excessive number of variables, because it could be not functional for the discrete choice analysis investigation. Therefore, the number of attributes was reduced to an appropriate number. Then, the most relevant and significant seven attributes of port sustainability and environmental performance were established, after a broad literature review.

Each of them were divided into sub-attributes. The first range of attributes corresponds to the actual indicator, the second range corresponds to the splitting of the indicator into various elements (sub-attributes) that help to define it, and the third degree (here not specified) of specification is a clear description of the influence and effects of what was defined in the second degree.

To be precise, the list of attributes is shown in Table 1. (with the detail of second grade specification).

Table 1. Port environmental attributes and sub-attributes selected for this study.

Attribute—1st Degree	Attribute–2nd Degree
Costs and Charges *(always present in this kind of analysis)*	Cost of supplied services for goods Port costs and fees Cost of supplied fuel Cost of supplied energy General port charges
Air Pollution	Atmospheric contaminant emissions: CO, NOX, SO, O, PM10 Atmospheric contaminant emissions: VOCs and particles Gas emissions with Greenhouse effects: CO2, N2O, CH4 Odor pollution Carbon footprint
Noise Pollution *(waterborne, airborne, structure borne)*	Noise caused by land traffic and maritime traffic Noise caused by container loading and unloading machinery Noise caused by civil works machinery Underwater noise
Water Pollution	Port water quality Accidental spills in port waters Quality of spilled wastewater
Resource Consumption	Electric energy consumption Fuel consumption Water consumption Waste creation and disposal Provision of LNG bunkering facilities
Port Capacity and Productivity	Supply at port berth Availability of feeder facilities Provision of services Congestion (waiting time and delay) Capacity to store and handle hazardous cargo Capacity to manage a big volume of traffic Restrictions on handling and restrictions in ports Experience, readiness and availability of port Quality of supplied services (quickness in operations, availability of machinery as cranes, . . .)
Port Environmental Improvement and Development	Existence of a certified environmental management system (EMS) under ISO, EMAS, PERS standardization Existence of environmental monitoring program (EMP) Existence of an environmental policy and legislation Presence of an environmental inventory of significant aspects (SEA) Targets for environmental improvement and port development Geographical advantages Relation with communities and human settlements

Source: own composition.

The identified indicators will be used in the next section for setting up the experiment.

4. Generation of the Experimental Design

This section sets up the experiment with attribute levels, experiment design and questionnaire design.

4.1. Definition of Attributes' Levels

The first step to proceed with the generation of the design was to define the attributes levels. This step is essential to describe the design approach from a formal point of view. In fact, we dealt with the specific characteristics of the generated design that presuppose the knowledge of the levels of attributes. As described before, two alternatives were introduced to develop a choice (Port A and Port B). Thanks to a solid elaboration on the methodology to implement a discrete choice analysis experiment, the levels assigned to the attributes are shown in Table 2.
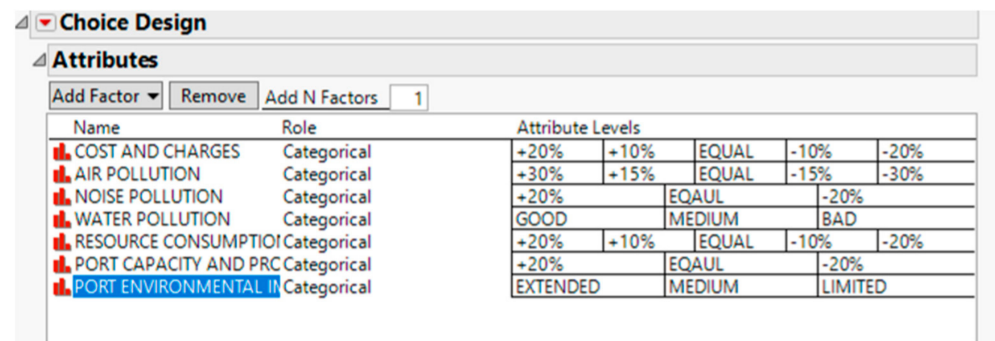
Table 2. Attributes' levels definition.

Cost and charges	20% higher port charges **(+20%)**	10% higher port charges **(+10%)**	Equal port charges compared with the current situation in any port the company docks **(EQUAL)**	10% lower port charges **(−10%)**	20% lower port charges **(−20%)**
Air pollution	30% higher air pollution, very high density of emissions allowed and no attention in preserving air quality **(+30%)**	15% higher air pollution, high density of emissions allowed and little attention in preserving air quality **(+15%)**	Equal air pollution, medium density of emissions allowed; this reflects the current situation **(EQUAL)**	15% lower air pollution, low density of emissions allowed and good attention in preserving air quality **(−15%)**	30%lower air pollution, very low density of emissions and much attention in preserving air quality **(−30%)**
Noise pollution	20% higher noise pollution, very expansive degree of noise allowed and no importance to avoid it **(+20%)**		Equal noise pollution, medium degree of noise pollution allowed, trying to maintain the current noise pollution threshold **(EQUAL)**	20% lower noise pollution, low expansive degree of noise allowed, trying to minimize it **(−20%)**	
Water pollution	High restrictions on water pollution and much attention in preserving water quality **(GOOD)**		Average restrictions on water pollution, trying to manage and maintain the current situation **(MEDIUM)**	Low restrictions on water pollution and not much attention in preserving water quality avoiding its degradation **(BAD)**	
Resource consumption	20% higher port resource consumption **(+20%)**	10% higher port resource consumption **(−10%)**	Equal port resource consumption compared with the current situation in any port the company docks **(EQUAL)**	10% lower port resource consumption **(−10%)**	20% lower port resource consumption **(−20%)**
Port capacity and productivity	20% higher port capacity and productivity, with much attention in having a good degree of productivity to get advantages and enhancements **(+20%)**		Equal port capacity and productivity, trying to manage and maintain the currently good degree of capacity and productivity **(EQUAL)**	20% lower port capacity and productivity, with carelessness in having new advantages and enhancements in capacity and productivity **(−20%)**	
Port environmental improvement and development	High degree of development and improvement, with much attention to any management aspect **(EXTENDED)**		Medium degree of development and improvement, with a good level of attention to any management aspect **(MEDIUM)**	Low degree of development and improvement, with no attention to all management aspects **(LIMITED)**	

Source: own composition.

4.2. Choice Experiment Design

Software produced by SAS Institute24, the JMP Pro 14 [24], was used for the design generation. Once the attributes were selected, the first step was to proceed by inserting them into the software, generating the first part of the chosen design as shown in Figure 2.
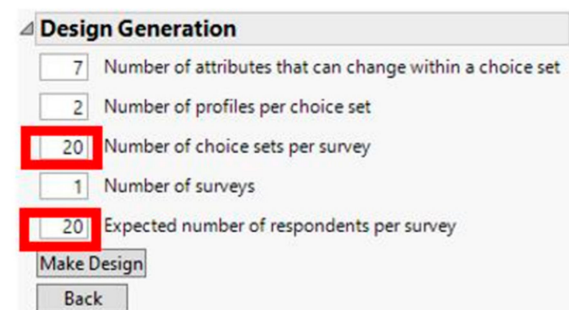
Figure 2. JMP attributes and levels definition in choice design—source: JMP.

Once it completed, there is the actual generation of the design by specifying the following features, as summarized in Figure 3:

- Number of attributes;
- Number of profiles for each choice or even number of alternatives for each choice;
- Number of choice sets or more improperly questions to be administered;
- Number of questionnaires or surveys to be generated;
- Expected number of respondents for each questionnaire or survey.

Thanks to this operation, all combinations of choice sets defined by attributes and their assigned levels were achieved. The combinations generated by the software were random combinations. This means that if one wanted to set the design more than once, the same combinations might not always be generated, rather they would always be different.

Figure 3. JMP design generation final phase–Source: JMP.

It can be seen how the number of questions or the set of choice within the questionnaire and the number of expected respondents is highlighted. It was decided, as a matter of adaptation to the structure of the questionnaire and since the number of attributes is still high, at 7, to establish 20 questions to be introduced in the questionnaire. At the same time, 20 possible questionnaire respondents were established (it is not assumed that all 20 then are willing to answer). This number is the number of companies that will actually be contacted. As shown, for the rest of the sections, two alternatives of choice were established (Port A and Port B), only one questionnaire, and confirmation of seven attributes.

4.3. Questionnaire Design

After obtaining the random combinations of the available attribute levels, the next step is to build the questionnaire. In order to receive good consideration from the companies interviewed, much attention was paid to the formulation of the questionnaire structure. The questionnaire, like any discrete analysis experiment, is based on a very specific question.

The question of focus in this research, the cornerstone of the questionnaire, is "how do container shipping companies choose their ports for cargo operations, taking into account port greening concept as much as possible?" The goal of the whole analysis, as already

known, is to show the implications of factors used in creating a good and functional concept of 'port greening', which has a lot of influence and massive control on the willingness and decision to choose which port to dock or not by a shipping company. The questionnaire is composed of 21 questions. Twenty are already known as "choice set", and the last one, the twenty-first, is an open question. The first twenty-choice set had the same request at its basis, directed to the interviewees. It is explicated as follows: "If you had to choose between the following two worldwide generic ports (A or B), which one would you choose in order to pursue a port greening concept as wide as possible?".

Thanks to the alternation of random combinations of attributes (with variation of their levels), every alternative (Port A or Port B) proposed a different "*choice ID*". Every interviewee had to read the questionnaire and upon their opinion, had to answer or choose the most suitable alternative between Port A and Port B. It has been specified in the description of the questionnaire presented to the interviewees that this twenty-first question, being an open question, was optional. Unfortunately, as is possible to see later, in this case, not everyone answered that question. As an example, in the Figure 4, the first choice set of the questionnaire is shown. One can see that there is a choice set (set 1), with two different choice IDs (1 and 2) and for each of them, there is a different combination of the attribute levels that make up the whole choice set.

CHOICE SET	CHOICE ID	COST AND CHARGES	AIR POLLUTION	NOISE POLLUTION	WATER POLLUTION	RESOURCE CONSUMPTION	PORT CAPACITY AND PRODUCTIVITY	PORT ENVIRON. DEVELOPM.
1	1	10%	-30%	-20%	MEDIUM	EQUAL	EQUAL	LIMITED
1	2	EQUAL	-15%	-20%	MEDIUM	20%	20%	LIMITED

Figure 4. First choice set—source: JMP.

5. Data Collection and Results Analysis

This section discusses data collection and executes the discrete choice analyses, the results of which are also presented subsequently.

5.1. Data Collection

The experiment of discrete analysis continued with a fundamental phase, which is that of data collection. The questionnaire was administered to the selected shipping companies in the period that went from 29 March to 24 May 2019, where the selected shipping companies are among the most important maritime companies in the world. The procedure with which these investigations were carried out was guided through some steps. The first step was to contact the companies via email and to illustrate the project situation in progress, with the request for their collaboration for the collection of data. The second step was, of course, the expectation of their response to the request done. The third step was the questionnaire administration to the partners who agreed to collaborate with us. A total of 14 companies collaborated on this research project. We have spoken to the higher-level managers of the different companies involved. The people we spoke to, reported the company's position on what we were asking, so confidence in the given answers is very high. The interviews were conducted in three different ways, namely:

- The direct mode in person (going to the company offices);
- Semi-direct mode via phone or video call;
- Indirect mode via email.

Of the 14 shipping companies interviewed (shown below in the Table 3), 13 companies explicitly requested that their response profiles were not to be made public, for privacy reasons.

Table 3. Container shipping companies interviewed.

Company	Nationality of the Company
APM Maersk	Denmark
MSC (Mediterranean Shipping Company)	Switzerland
COSCO Group (China Ocean Shipping Company)	China
CMA-CGM Group	France
Hapag-Lloyd AG	Germany
Ming Marine Transport Corporation	China/Taiwan
HMM (Hyundai Merchant Marine)	South Korea
OOCL Orient Overseas Container Lines	Hong Kong
Arkas Container Transport Line	Turkey
X-Press Feeders Group	Singapore
Grimaldi Group	Italy
StreamLines (Sea-trade BV)	Scotland
ZIM (Integrated Shipping Services Ltd.)	Israel
ONE (Ocean Network Express)	Singapore/Japan

Source: own composition.

5.2. Results Analysis

The next phase after collecting the data obtained from the questionnaires submitted to the various companies was to process all the data using JMP. Thanks to a *Multinomial Logit Model*, that this software uses, a statistical analysis model of the collected data was developed and generated. They were all conducted within a worktable called '*Selection Attempts*', and from that worktable, the next step of elaboration of the model was developed. The procedure for the analysis of data in JMP is illustrated below step by step, in order to show how the final formulation of the model has been obtained. In Figure 5, it is possible to see how the analysis of the data starts.
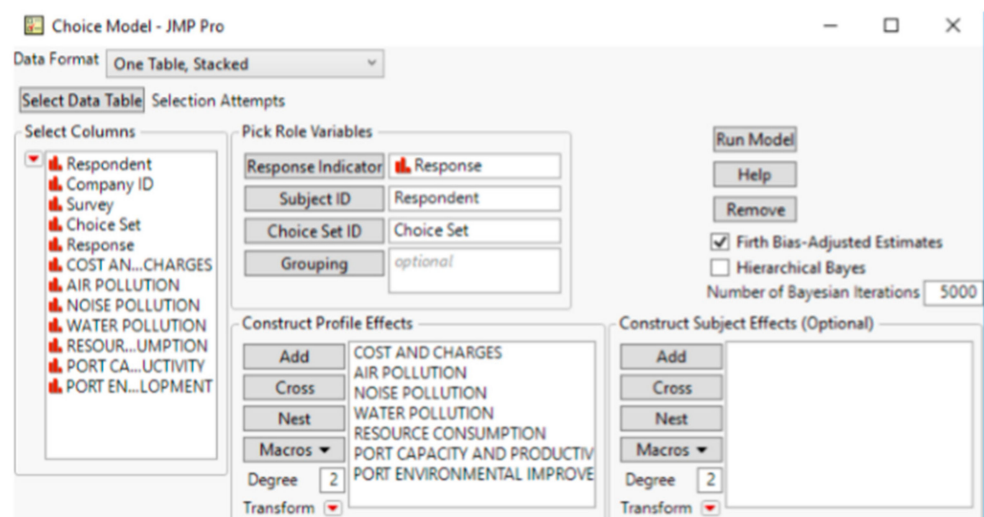

Figure 5. "Choice Model" window: Pick Role Variables chosen to run the model and attributes selection—source: JMP.

By clicking on the '*Run Model*' box, the first interpretation of the data was finally obtained. A first overview of the effects of the results are summarily shown in Figure 6. It is called the '*Effect Summary*'. The Effect Summary report appears if the model contains

more than one effect and if it can be calculated quickly. It lists the effects estimated by the model and gives a plot of the *Log-Worth* (or FDR25 (False Discovery Rate) Log-Worth) values for these effects. The '*Effect Summary*' window contains the following columns, as shown in Figure 6.

- *Source*—lists the model effects, sorted by ascending *p*-values;
- *Log-Worth*—shows the Log-Worth for each model effect, defined as $-\log 10$ *(p-value)*. This transformation adjusts *p*-values to provide an appropriate scale for graphing. A value that exceeds 2 is significant at the 0.01 level (because, $-\log 10$ (0.01) = 2);
- *FDR Log-Worth*—shows the False Discovery Rate Log-Worth for each model effect, defined as $-\log 10$ *FDR p—value*. This is the best statistic for plotting and assessing significance. This is not fundamental in this analysis;
- *Bar Chart*—shows a bar chart of the Log-Worth (or FDR Log-Worth) values. The graph has dashed vertical lines at integer values and a blue reference line at 2;
- *p-Value*—shows the *p*-value for each model effect. This is the *p*-value corresponding to the significance test displayed in the Likelihood Ratio Tests report.
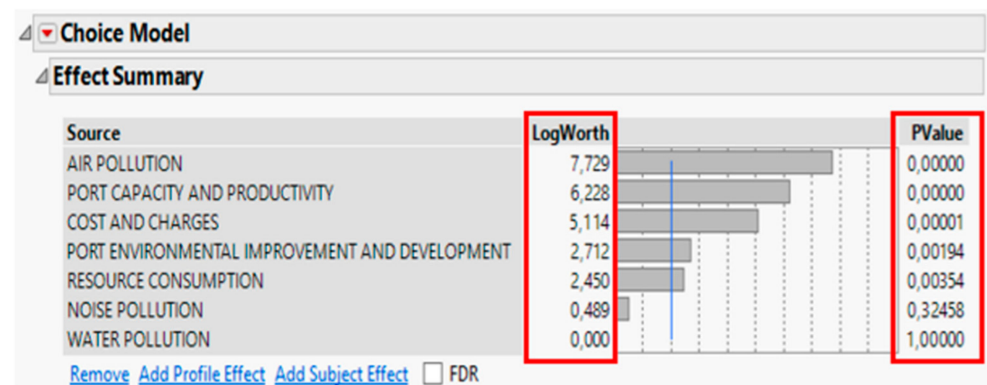

Figure 6. "Effect Summary" window—Source: JMP.

A second element found in the computed results is the '*Parameter Estimates*' window (Figure 7). The '*Parameter Estimates*' report gives estimates and standard errors of the coefficients of utility associated with the effects listed in the term column. The coefficients associated with attributes are sometimes referred to as *part-worths*.

It is possible to note (by setting aside the value of the standard error as said) that values appear with the positive sign and others with the negative sign. These are the β parameters found in the utility formula:

$$U_{jsn} = x'_{jsn}\beta + \varepsilon_{jsn} \tag{4}$$

The software has computed the overall significance and the relative importance of the seven attributes by means of likelihood ratio tests and present the parameter estimates or *marginal utility* values of the attribute levels.

The third element found in the computed results is the '*Likelihood Ratio Tests*' window, shown in Figure 8.

According to Figure 8, reported directly from JMP, it is possible to observe the following components:

- *L-R ChiSquare*—the value of the likelihood ratio ChiSquare statistic for a test of the corresponding effect;
- *DF*—the degrees of freedom for the ChiSquare test;
- *Prob>ChiSquare*—the *p*-value for the ChiSquare test;
- *Bar Graph*—shows a bar chart of the L-R ChiSquare values.

Parameter Estimates

Term	Estimate	Std Error
COST AND CHARGES[+20%]	-0,69183138	0,3503623605
COST AND CHARGES[+10%]	-0,07407801	0,3135864266
COST AND CHARGES[EQUAL]	-0,24903309	0,2364471810
COST AND CHARGES[-10%]	0,75284909	0,2492862959
AIR POLLUTION[+30%]	-1,29207732	0,3393376294
AIR POLLUTION[+15%]	-0,52204796	0,3238607997
AIR POLLUTION[EQUAL]	0,39250107	0,3724860454
AIR POLLUTION[-15%]	0,07382871	0,1934258021
NOISE POLLUTION[+20%]	0,27024088	0,2149345306
NOISE POLLUTION[EQUAL]	-0,05589409	0,2187218525
WATER POLLUTION[GOOD]	0,08720195	0,3340190644
WATER POLLUTION[MEDIUM]	0,30282183	0,3548636065
RESOURCE CONSUMPTION[+20%]	-0,70226116	0,2846660634
RESOURCE CONSUMPTION[+10%]	0,28761076	0,3569299950
RESOURCE CONSUMPTION[EQUAL]	-0,36723299	0,2736792659
RESOURCE CONSUMPTION[-10%]	0,48374008	0,3205109746
PORT CAPACITY AND PRODUCTIVITY[+20%]	1,06489268	0,3147255029
PORT CAPACITY AND PRODUCTIVITY[EQUAL]	-0,17251365	0,4194696814
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT[EXTENDED]	1,01368239	0,3190240640
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT[MEDIUM]	0,19817090	0,3190240640

Figure 7. "Parameter Estimates" window—source: JMP.

Likelihood Ratio Tests

Source	L-R ChiSquare	DF	Prob>ChiSq	
COST AND CHARGES	29,033	4	<,0001*	
AIR POLLUTION	41,767	4	<,0001*	
NOISE POLLUTION	2,250	2	0,3246	
WATER POLLUTION	0,000	2	1,0000	
RESOURCE CONSUMPTION	15,639	4	0,0035*	
PORT CAPACITY AND PRODUCTIVITY	28,679	2	<,0001*	
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT	12,489	2	0,0019*	

Figure 8. "Likelihood Ratio Tests" window–Source: JMP.

5.3. Results Interpretation

These first aspects of the results obtained are of fundamental importance and constitute future interpretations. Firstly, it is necessary to mention some theoretical considerations that will help to make the necessary observations for further analysis of the results.

5.3.1. *p*-Values as Significative Values

The *p*-value, or calculated probability, is the probability of finding the observed effect. Conventionally the 5%, 1% and 0.1% ($p < 0.05$, $p < 0.01$, $p < 0.001$) levels have been used. These numbers can give a false sense of security. However, it is possible to try to optimize all stages of the research to minimize sources of uncertainty.

When presenting *p*-values, some groups find it helpful to use the asterisk rating system as well as quoting the *p*-value:

- $p < 0.05$ *;
- $p < 0.01$ **;
- $p < 0.001$.

Most authors refer to "*statistically significant*" as $p < 0.05$ and "*statistically highly significant*" as $p < 0.001$ (less than one in a thousand chance of being wrong).

5.3.2. Results' Meaning

Having made these theoretical considerations, it is necessary to give an interpretation of the results obtained.

Looking at the '*Effect Summary*' window, you can see that some of the attributes in play are very significant, based on the considerations expressed regarding the *p*-values. In this analysis, it was decided to take into consideration the fact that a probability value must be highly significant and have less than a thousand possibilities of being wrong and therefore ($p < 0.001$). Keeping this hypothesis under observation, we can see that the attributes that respect an index of probability values of this type and therefore are statistically very significant are:

- Air pollution;
- Port capacity and productivity;
- Cost and charges.

The other factors exceed this limit. The assumption that is possible to make is that even if the port environmental improvement and development attribute has a probability value just greater than 0.001 (it is, in fact, 0.00194), it can also be considered statistically significant in its probabilistic value. The rest of the attributes that we cannot consider statistically significant, according to the previous assumption, therefore remain to be analyzed, since their probability values are all much higher than the established value 0.001. These are:

- Resource consumption;
- Noise pollution;
- Water pollution.

All of the above is summed up in Figure 9, which establishes a ranking about the importance of these attributes according to the Multinomial Logit Model.
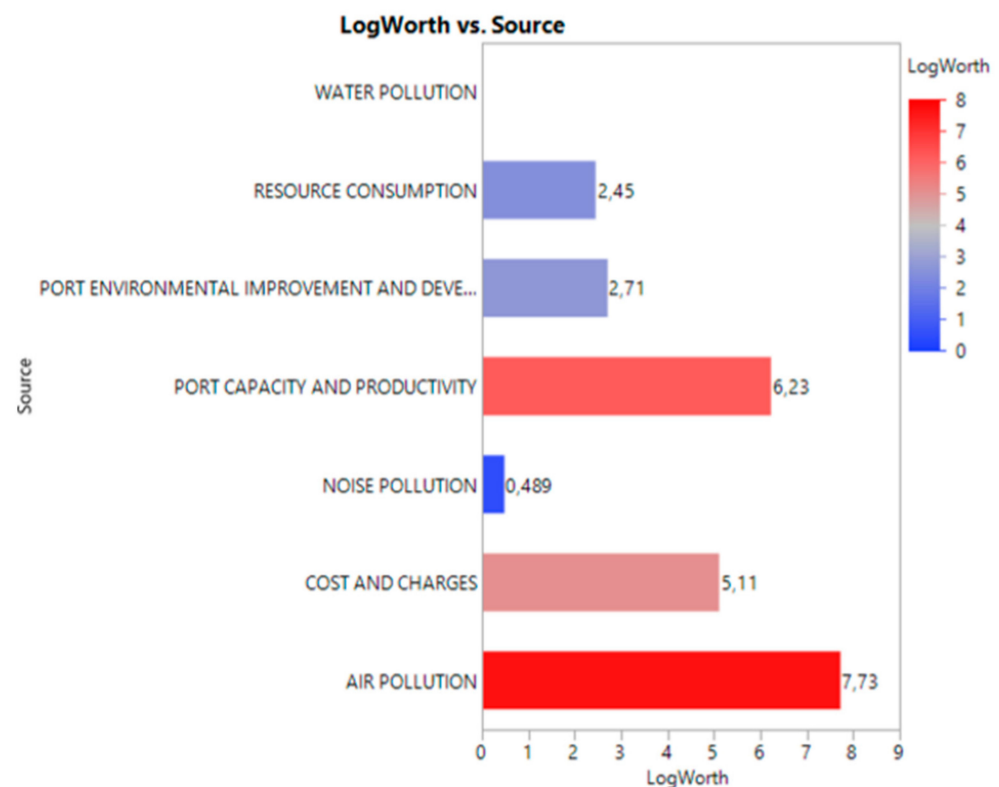

Figure 9. *p*-Values in Log-Worth scale: MNL ranking attributes—source: JMP.

The task ahead is to find a method to elaborate on the meaning of these parameters and also give them a probabilistic meaning in order to make them statistically significant.

It can be observed that among these three parameters, there are water pollution and noise pollution. These two environmental monitoring parameters, which normally (in the common logic) are two fundamental elements for the concept of sustainability and ecology, in this ranking, play a marginal role.

This means that shipping companies involved in the research have set aside these two aspects, preferring aspects that are more important and decisive for them, such as the first three attributes of the ranking (air pollution, cost and charges and port capacity and productivity).

The work to do has been to implement a model in which only these three attributes were involved, thus establishing a new profile of effects, this time playing only with three attributes and not with all seven. Then again, by running the model, the following results are obtained (as reported in Figure 10):

Figure 10. "Effect Summary" window for the three attributes—source: JMP.

As can be seen from these first results, the resource consumption attribute acquires particular importance.

This attribute stands out from the other two and provides a statistically significant probability value, in fact, 0.00055, which is <0.001. Although not statistically significant, the other two parameters remain in their values and, above all, are effectively relegated to the last two positions of the established ranking.

It sounds strange, but according to the analysis, the companies involved do not give any weight or importance to these two attributes (noise and water pollution).

A further iteration was carried out, now only for water and noise pollution, but the result that emerges is that they continue to be not statistically significant. As is possible to see from Figure 11, the *p*-values associated are higher than 0.001.

Figure 11. "Effect Summary" for noise and water pollution—source: Own composition from JMP.

It is, therefore, unnecessary to go in depth and just to accept the condition presented, in which these two attributes cover a marginal role in the ranking, which is now definitely established:

1. *Air pollution;*
2. *Port capacity and productivity;*
3. *Cost and charges;*
4. *Port environmental improvement and development;*
5. *Resource consumption;*
6. *Noise pollution;*
7. *Water pollution.*

5.4. Implication for the Container Shipping Companies

From the analysis of the results obtained previously, it is noted that the main elements of influence for the ecology of a port are the factors of air pollution, port capacity, productivity and the costs, and then gradually all the others.

Based on this observation, some implications for the companies interviewed are highlighted.

Shipping companies tend to give high importance mainly to one factor: Air pollution. The decisions of maritime transport managers are heavily influenced by this type of parameter. This happens because, currently, there are regulations (issued by international organizations, e.g., IMO—International Maritime Organization) that, through strict limitations and guidance, aim to reduce harmful emissions into the air (not only by shipping companies, but by any type of transport) [11]. Moreover, there is increasing pressure by shipping companies' customers, the shippers. They more frequently request green supply chains, including maritime shipping. That happens in turn under pressure by their (final) customers and/or by financiers who are less, or not at all, willing to lend money to projects and investments that are insufficiently green.

If these guidelines and limits were not respected and therefore violated, specific administrative, financial and legal penalties would be applied. Therefore, great importance is attributed to the observance of these policies [25–28].

In addition, to help limit harmful emissions into the air, in recent years, many solutions and mitigation measures have been developed in the maritime transport sector.

These are technological, regulatory and operational solutions that not only help reduce air pollution, but also provide benefits and advantages from other points of view.

In fact, just for instance, the use of alternative fuels, in addition to mitigating and reducing air pollution, can improve the performance of ships, as it can reduce the consumption of resources and energy as well as the production of waste and exhaust products.

With respect to port capacity and productivity, it is clear that the importance of this factor is highlighted by the increasing control that shipping companies try to gain over non-shipping parts of the chain: Port terminals in the first place, but increasingly also hinterland connections and inland terminals. They do so by acquiring stakes in port terminals, setting up their own terminal subsidiaries, or setting up alliances with terminal operators. Greening supply chains will imply that an attempt is made to shift hinterland operations away from road to barge and rail. This requires different types of capacity at port terminals than what currently often applies.

Finally, with respect to costs and charges, it is clear that port dues, but especially charges asked by port terminal operators, matter. Whereas environmental expenses are 'hidden' costs in the chain, port dues and terminal charges are out-of-pocket costs, and therefore immediately visible and felt. It is important that sufficient competition between ports and terminals is maintained, so as to avoid monopoly rents being charged. At the same time, shipping companies exert substantial market power on most routes, also in their negotiations with port terminals. The costs of green port investments may further be charged to the shipping companies, so there is a direct link between greening ports and port dues and/or terminal charges.

6. Conclusions

In this research, a very sensitive topic has been addressed, which is of great importance nowadays in the transport sector. All the results obtained from this study have highlighted some very significant aspects of the subject.

Maritime transport has various effects on the environment, and the mitigation measures for these effects acquire considerable importance. These mitigation measures can be summarized, according to this research in five guidelines, which serve to give a solid basis and concrete support to those who intend to address the topic in future studies. It is, in fact, a matter of keeping in mind that these mitigation and prevention measures can be included in:

- Regulations and enforcement;
- Innovative technological solutions and adaptations;
- Regional and international initiatives aimed at paying greater attention to the concept of sustainability;
- Incentives and progress (technological, environmental and social);
- Awareness of the subjects involved in the study of these topics (awareness on the subject, of those directly involved and of those who would be interested in it transversally).

The regulations and the application were considered to be an essential management solution to prevent the effects of maritime transport on the environment and to direct the maritime industry towards sustainability. Over the years, we tend to use more and more strict and direct regulations, strictly targeted to the various issues to be managed. Alongside the regulations, the technological and innovative solutions of the management systems find their place.

Encouragingly, the shipping industry is considered a leader in clean technology. This is also accompanied by the aspect of regional, national and international environmental initiatives in order to facilitate the formation of a sustainable and green maritime industry as much as possible.

An important aspect worth considering is that for which there is a close economic dependence between the sustainable development of ports and the economic growth of a region or an entire country in which the port operates. Without going in-depth with economic reflections, it is enough to simply mention how port development has been one of the critical elements of the economic growth of some world powers.

The greater the sustainability policies of a country (especially in the transport sector), the greater the chances of a flourishing economic development of the country itself. This is because, with sustainability practices (ports in this case, but in general in all other cases) we tend above all to rationalize the use of environmental resources. Consequently, a lower expenditure of economic resources will be obtained in the long term, with social and political benefits [29,30].

These conclusions also lead to further questions for subsequent studies. The most relevant question that has been repeatedly considered during this research is where can the boundaries of sustainable port development be given? Further, are there any limitations or is there no possibility of indicating a point of arrival that tells us when a port and the operations carried out there are considered sustainable at the maximum level? Furthermore, what could be future developments regarding the reduction of harmful emissions into the air from maritime transport? Will technological solutions such as new fuels (LSF—Low Sulphur Fuels, LNG–Liquefied Natural Gas, biofuels, hydrogen fuel cells, etc.) work for a long time, or are they only temporary solutions? Is it appropriate to already talk now about the concept of zero emission shipping/vessel (ZEV)? Could this concept also be easily extended to container ships dedicated to commercial transport? These questions are the basis of future studies and future research on this topic.

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