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

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To my grandfather,

my greatest master of life.

"The real voyage of discovery consists not

new landscape, but in having new eyes."

Marcel Proust

ABSTRACT

Background

In the last decades, the processes managed by shipping companies and companies operating in the maritime logistics sector have had much more than negative effects on the environment. The ecologically green and sustainable situation of the maritime environment (in its entirety) is increasingly threatened by the harmful influence of some apparently simple factors, but with a deep environmental meaning. Therefore, this research work deals with environmental issues in port terminals. We will try to highlight the importance that the above-mentioned factors occupy in the concept of "port greening", that will be well-defined in the central body of the work, verifying where necessary, the safety and prevention measures that can be adopted in order to best compete towards a healthy concept of port greening.

Justification of research

The following work arises from the idea of comparing the opinions of various shipping companies involved in port operations (specifically container transport) to be able to realize how each act according to its different criteria to contribute to the previously - mentioned concept of port greening. The work justifies in the fact that there is an absolute need to balance the mode of action of all the maritime logistics companies in order to arrive at the final concept of a green port.

Purpose

The purpose of this research is to highlight the best environmental and non-environmental factors that contribute to degrading and make a port environment less suitable. It analyzes them in detail with probabilistic criteria and after a complete analysis, which boasts the collaboration and participation of some of the most important maritime logistics companies in the world, defining the criteria for managing these parameters. All this is done in accordance with the needs and occurrences of the various logistics companies.

As stated in various documents that previously covered these topics, new interpretations and new measures can set the wheels in motion for change and development.
This study makes contributions to our knowledge of the sustainable management of a container terminal and is essentially significant for professionals and academics.
In terms of academic perspective, it is able to demonstrate an accurate understanding of container terminal management explaining which aspects to intervene based on the results obtained, without hindering the various operations of logistic shipowners.
This is why many previous types of research have explained the problems of sustainability in ports, focusing above all on environmental aspects.
The basic purpose of the work, in addition to what has been described so far, is in practice to guide and sensitize those who work in the sector with regard to the problems that arise and develop in relation to port ecology.

Design/Methodology/Approach

This work takes a qualitative research approach. Structured on a discrete choice analysis of the parameters, which until now has been discussed, conducted with the initial aid of combinatorial questionnaires administered, through direct interviews (in person), indirect (via email), semi-direct (via telephone devices and video telephones), to the participants (logistic partners).
For the method of analyzing the results of these questionnaires, a totally probabilistic approach was used, with the aid of the JMP software.
Thanks to this program, statistics have been drawn out that have allowed us to focus our analysis on certain operational conclusions.

Findings

The results of this research establish a ranking of the parameters involved in the concept of port greening, in order to have in hand a clear situation on what to do and what to work on in order to improve the ecological conditions in order to pursue the concept of a green port.
The criteria most involved from an environmental point of view, as it turned out later, will be air pollution, solid waste management, and solid contamination, water pollution and water quality, as well as noise pollution and resource consumption.

The economic and administrative aspects will also be involved, such as port costs and expenses, and port development in terms of capacity and productivity.

ACKNOWLEDGMENTS

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Still other thanks to Thierry Vanelslander for the precious contribution that led me to be able to interact during the period of my stay in Antwerp with the major shipping logistics container companies based in the port of the city. He has the merit of having put me in touch with them.

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Last tanks are for all the **shipping companies** that have taken part in this research. They are mentioned on the following page.

MAERSK LINE

msc

CMA CGM

Hapag-Lloyd

COSCO SHIPPING

ONE
OCEAN NETWORK EXPRESS

OOCL

YANG MING

ZIM

HMM

STREAMLINE
SHIPPING GROUP

GRIMALDI GROUP

X-PRESS FEEDERS

ARKAS

GENERAL INDEX

INDEX OF FIGURES 5
INDEX OF TABLES 8
INDEX OF APPENDIX FIGURES 9
INDEX OF APPENDIX TABLES 10
INDEX OF ABBREVIATIONS 11
1 INTRODUCTION 13
2 RELATED CONCEPTS TO MARITIME TRANSPORT 15
2.1 Shipping growth 15
2.2 Maritime transport and ship evolution 17
2.3 Port operations and relation with sustainability 21
2.4 Environmental problems 22
2.5 Role of the ports 23
2.6 Environmental management in ports 24
3 CONCEPTS AND CRITERIA ABOUT GREEN PORTS 26
3.1 Introduction to sustainability and green port concept 26
3.2 Opportunities for green and sustainable ports 27
3.3 Perceived challenges 27
3.4 Green objectives 29
3.4.1 Landlord function 29
3.4.2 Regulatory function 30
3.4.3 Operation function 31
3.4.4 Community function 32
3.5 Green and Smart ports: two inextricable concepts 32

3.6 Port Sustainability Indicators (PSI) 35

3.7 Green ports regulation 37

4 CASE OF STUDY AND METHODOLOGY 40

4.1 Problem definition of the case of study 40

4.2 Methodology of Discrete Choice Analysis (DCA): what is and what it needs 42

4.3 Differences between discrete choice analysis and conjoint analysis 45

4.4 Stated and revealed preference data 48

4.5 Operate with stated preference data 50

4.6 Behind the Discrete Choice Analysis 51

5 THE MODEL 53

5.1 Multinomial Logit Model (MNL) 53

5.2 Notes concerning the estimation of the discrete choice models 55

5.2.1 The maximum likelihood estimation 55

5.2.2 The likelihood ratio test 56

6 DEFINITION OF ALTERNATIVES AND ATTRIBUTES 59

6.1 Definition of alternatives 59

6.2 Definition of attributes 59

6.3 Port Sustainability Indicators according to “ESPO ENVIRONMENTAL REPORT 2018” 61

6.4 Port Sustainability Indicators according to other researches 65

6.5 Our Port Sustainability Indicators as attributes 74

6.6 Description of chosen attributes 84

6.6.1 Air pollution 85

6.6.2 Water pollution 87

6.6.3 Noise pollution 88

6.6.4 Resource consumption 89

6.6.5 Port capacity and productivity ... 90
6.6.6 Port environmental improvement and development ... 91
6.6.7 Cost and charges ... 92
7 GENERATION OF THE EXPERIMENTAL DESIGN ... 94
7.1 Definition of attributes' levels ... 94
7.2 Full factorial and fractional factorial design ... 96
7.3 Labelled and unlabelled choice experiments ... 97
7.4 Bayesian Optimal Design consideration ... 97
7.5 JMP Pro 14 and choice experiment design ... 99
7.6 Questionnaire design ... 103
8 DATA COLLECTION AND RESULTS ANALYSIS ... 106
8.1 Data collection ... 106
8.2 Results analysis ... 108
8.3 Results' interpretation ... 114
8.3.1 P-values as significative value ... 114
8.3.2 L-R ChiSquare Test ... 115
8.4 Effect Summary window interpretation ... 116
8.5 Parameter Estimates window interpretation ... 117
8.6 Utility profiler window interpretation ... 120
8.7 Likelihood Ratio Test window interpretation ... 122
8.8 Not statistically significant *P*-values interpretation ... 124
9 MANAGEMENT AND PREVENTION MEASURES ... 130
9.1 Measures proposed by interviewed shipping companies ... 131
9.2 Measures analyzed in the literature ... 138
9.2.1 Identification of Instruments ... 139
9.2.2 Identification and Selection of Evaluation Criteria ... 140

9.2.3 Evaluation criteria and following ranking of instruments 140

9.3 Technical measures and operational measures 141

9.3.1 Technical Measures 141

9.3.2 Operational Measures 143

9.4 The Regulatory Regime 144

9.5 Routes to compliance: Alternative Sources of Energy 145

9.6 Routes to compliance: Abatement Technology 147

10 CONCLUSIONS 149

11 REFERENCES 152

A-APPENDIX 160

B-APPENDIX 162

C-APPENDIX 176

D-APPENDIX 192

INDEX OF FIGURES

Figure 1.1 A container dock in the Port of Antwerp during loading and unloading operations (Source: own source) 14
Figure 2.1 International seaborne trade by millions of tons loaded per year (Source: Maritime Transport Review 2018) 15
Figure 2.2 World seaborne trade growth forecast 2018-2023 (Source: Maritime Transport Review 2018) 16
Figure 2.3 Global containerized trade 1996-2018 (Million 20-foot equivalent units and percentage annual change) (Source: Maritime Transport Review 2018) 16
Figure 2.4 Estimated containerized cargo flows on major East-West container trade routes 1995-2018 by Million 20-foot equivalent units (Source: Maritime Transport Review 2018) . 17
Figure 2.5 World fleet and ownerships (Source: Maritime Transport Review 2018) 18
Figure 2.6 Annual growth of world fleet and seaborne trade in percentage (Source: Maritime Transport Review 2018) 19
Figure 2.7 Share of world fleet in dead-weight tonnage by principal vessel type 1980-2018 by percentage (Source: Maritime Transport Review 2018) 19
Figure 2.8 Growth container ship's carrying capacity in TEU since 1968 (Source: Assessment of Sustainability initiatives in port operations: an overview of global and Canadian ports).... 20
Figure 2.9 Top ten environmental priorities by ESPO research (Source: ESPO environmental report 2018) 22
Figure 3.1 Concept map of a green and intelligent port integration (Source: Constructing governance framework of a green and smart port) 35
Figure 3.2 Timeline of legislation about green port (Source: Sustainable port operation management: green performance criteria for container terminals) 37
Figure 4.1 Scheme of the phases of the research (Source: own composition) 41
Figure 4.2 Conjoint Analysis division (Source: own composition) 43
Figure 6.1 Top Ten Environmental Priorities (Source: ESPO Environmental Report 2018) . 64
Figure 6.2 Indicators according to Darbra analysis (Source: Identification and selection of Environmental Performance Indicators for sustainable port development) 68

Figure 6.3 Environmental indicators from previous researches (Source: Assessment of port sustainability indicators in the sustainability reporting process)....70
Figure 6.4 Social indicators from previous researches (Source: Assessment of port sustainability indicators in the sustainability reporting process)....70
Figure 6.5 Air, noise, odour pollution impacts according to Peris-Mora (Source: Development of a system of indicators for sustainable port management)....71
Figure 6.6 Water, soil pollution and waste creation impacts according to Peris-Mora (Source: Development of a system of indicators for sustainable port management)....72
Figure 6.7 Resource consumption and other impacts according to Peris-Mora (Source: Development of a system of indicators for sustainable port management)....73
Figure 6.8 Discharge operation process of container ships with influencing elements for the greening grade of the port (Source: Analysis on low-carbon and green container port building goal system)....84
Figure 7.1 JMP logo (JMP website download)....99
Figure 7.2 JMP attributes and levels definition in choice design (Source: JMP)....100
Figure 7.3 JMP prior mean values specification (Source: JMP)....101
Figure 7.4 JMP prior variance matrix as an identity matrix (Source: JMP)....102
Figure 7.5 JMP design generation final phase (Source: JMP)....103
Figure 7.6 Question 1 of the survey (Source: own composition)....104
Figure 8.1 Choice Model window to select the elements to run the model (Source: JMP)....109
Figure 8.2 Choice Model window: Pick Role Variables chosen to run the model and attributes selection (Source: JMP)....109
Figure 8.3 Effect Summary window (Source: JMP)....111
Figure 8.4 Parameter Estimates window (Source: JMP)....112
Figure 8.5 Likelihood Ratio Tests window (Source: JMP)....113
Figure 8.6 Effect Marginals window 1 (Source: JMP)....119
Figure 8.7 Effect Marginals window 2 (Source: JMP)....119
Figure 8.8 Effect Marginals window 3 (Source: JMP)....119
Figure 8.9 Utility Profiler for Cost and Charges, Air, Noise, Water Pollution (Source: JMP)....120
Figure 8.10 Utility Profiler for Resource Consumption, Port Capacity and Productivity and Port Environmental Improvement and Development (Source: JMP)....121

Figure 8.11 Utility Profiler with -30% level for Air Pollution (Source: JMP)......................121
Figure 8.12 Comparison between Effect Summary and Likelihood Ratio Test window P-values (Source: JMP)..123
Figure 8.13 P-values in LogWorth scale: MNL ranking attributes (Source: JMP)...............124
Figure 8.14 Choice Model window: Pick Role Variables chosen to run the model and attributes selection (Source: JMP)...125
Figure 8.15 Effect Summary window for the three attributes (Source: JMP).......................126
Figure 8.16 P-values in LogWorth scale for the three attributes: MNL ranking attributes (Source: JMP)..126
Figure 8.17 Parameter Estimates window for the three attributes (Source: JMP) 127
Figure 8.18 Likelihood Ratio Test window for the three parameters (Source: JMP)............127
Figure 8.19 Effect Marginals window for the three attributes (Source: JMP) 128
Figure 8.20 Effect Summary for Noise and Water Pollution (Source: JMP)........................128
Figure 8.21 Ranking of attributes according to P-value trend in LogWorth scale (Source: JMP) 129
Figure 9.1 Ranking of attributes according to P-value trend in LogWorth scale (Source: JMP) 130
Figure 9.2 Resource Consumption according to companies (Source: own composition).....131
Figure 9.3 Environmental Quality according to companies (Source: own composition)......135
Figure 9.4 Categories of instruments (Source: The greening of terminal concessions in seaports)..140
Figure 10.1 Container ship in Port of Antwerp (Source: own source).................................151
Figure 10.2 Aerial view of the Port of Antwerp in the evening (Source: own source).........151

INDEX OF TABLES

Table 3.1 Landlord function (Source: Environmental sustainability in seaports: a framework for successful innovation) 30
Table 3.2 *Regulatory function (Source: Environmental sustainability in seaports: a framework for successful innovation)* 31
Table 3.3 Operation function (Source: Environmental sustainability in seaports: a framework for successful innovation) 31
Table 3.4 Community function (Source: Environmental sustainability in seaports: a framework for successful innovation) 32
Table 3.5 The development concept for green and smart ports (Source: Constructing governance framework of a green and smart port) 34
Table 3.6 General characteristics of port sustainability indicators (Source: Assessment of port sustainability indicators in the sustainability reporting process) 36
Table 4.1 Differences between stated and revealed preference data (Source: The airport choice for scheduled freighter operations in Europe) 49
Table 6.1 Environmental Management Indicators according to ESPO (Source: ESPO Environmental Report 2018) 62
Table 6.2 Environmental Monitoring Indicators according to ESPO (Source: ESPO Environmental Report 2018) 63
Table 6.3 General characteristics of port sustainability indicators (Source: Development of a systems of indicators for sustainable port management) 67
Table 6.4 Port Environmental Indicators selected for this study (Source: own composition) 82
Table 6.5 Waste creation indicator and its grades (Source: own composition) 83
Table 7.1 First choice set (Source: own composition) 105
Table 8.1 Shipping Companies contacted for the collaboration (Source: own composition) 108
Table 8.2 Attribute assessment on P-values (Source: own composition according to JMP) 123

INDEX OF APPENDIX FIGURES

Figure Appendix 1.D Source-P-values (Source: JMP) 194
Figure Appendix 2.D Source- LogWorth (Source: JMP) 195
Figure Appendix 3.D Estimate Parameters-Term (attributes' levels) (Source: JMP) 196
Figure Appendix 4.D Marginal utility Cost and Charges (Source: JMP) 197
Figure Appendix 5.D Marginal utility Air Pollution (Source: JMP) 197
Figure Appendix 6.D Marginal utility Noise Pollution (Source: JMP) 198
Figure Appendix 7.D Marginal utility Water Pollution (Source: JMP) 198
Figure Appendix 8.D Marginal utility Resource Consumption (Source: JMP) 199
Figure Appendix 9.D Marginal utility Port Capacity and Productivity (Source: JMP) 199
Figure Appendix 10.D Marginal utility Port Environmental Improvement and Development (Source: JMP) 200
Figure Appendix 11.D Source – LogWorth for the three attributes (Source: JMP) 201
Figure Appendix 12.D Source – P-values for the three attributes (Source: JMP) 202
Figure Appendix 13.D Estimate Parameters - Term (attributes' levels for the three attributes) (Source: JMP) 202
Figure Appendix 14.D Marginal Utility Noise Pollution (Source: JMP) 203
Figure Appendix 15.D Marginal Utility Water Pollution (Source: JMP) 203
Figure Appendix 16.D Marginal Utility Resource Consumption (Source: JMP) 204

INDEX OF APPENDIX TABLES

Table Appendix 1.A Random combinations for the survey from JMP (Source: JMP) 161
Table Appendix 2.C Survey's responses by companies (Source: own composition). 191

INDEX OF ABBREVIATIONS

AIC	Akaike's Information Criterion
BIC	Bayesian Information Criterion
CBD	Biodiversity Convention
CNG	Compressed Natural Gas
DCA	Discrete Choice Analysis
DF	Degrees of Freedom
DSHAR	Dangerous Goods in Harbour Area Regulations
ECA	Emissions Control Area
ECI	Environmental Condition Indicator
ECSA	European Community Shipowners' Association
EEA	European Environmental Agency
EEDI	Energy Efficiency Design Index
EMP	Environmental Monitoring Programme
EMS	Environmental Management System
EMAS	Eco-management and Audit System
EPA	Environmental Protection Act
EPI	Environmental Performance Indicator
ESD	Ecologically Sustainable Development
ESPO	European Sea Ports Organization
EU	European Union
FAHP	Fuzzy Analytic Hierarchy Process
FDR	False Discovery Rate
GHG	Green-House-Gases
GMEP	Green Marine Environmental Program
GPU	Ground Power Unit
GT	Gross Tonnage
HAM	Humid Air Motor
HFO	Heavy Fuel Oil
IAPH	International Port Association

ICS	International Chamber of Shipping
IMO	International Maritime Organization
IMDG	International Maritime Dangerous Goods Code
ISO	International Standard Organization
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LR	Likelihood Ratio
LSF	Low Sulphur Fuels
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine Diesel Oil
MNL	Multinomial Logit Model
MPI	Management Performance Indicators
NGO	Non- Governmental Organization
ODCE	Organization for Economic Co-operation and Development
ODS	Ozone Depleting Substances
OPI	Operational Performance Indicators
OPS	Onshore Power Supply
OTA	Office of Technology Assessment
PERS	Port Environmental Review System
PORTOPIA	Port Observatory for Performance Indicator Analysis
PSI	Performance Sustainability Indicator
PVC	Polyvinyl Chloride
RUM	Random Utility Model
SCR	Selective Catalytic Reduction
SDM	Self Diagnosis Method
SEA	Significant Environmental Aspects
SFOC	Specific Fuel Oil Consumption
TBT	Tributyltin
TEIP	Tool Environmental Indicators in Ports
UNCTAD	United Nations Conference on Trade and Development
VOC	Volatile Organic Compounds

1 INTRODUCTION

Ports offer prosperity by facilitating maritime transport and offering economic and social development to the host community.

For centuries, ports have functioned as an economic engine, allowing the transport of essential goods and services to human society throughout the world.

Ports are portals for international trade and play a vital role in the world economy by embracing shipping, which is now considered to be the most efficient and relatively environmental friendly low-cost mode of transport.

Today the shipbuilding industry carries around 90% of world trade in volume, but while serving world trade and supporting economic and social well-being around the world, port operations can also have negative effects on the environment.

Air emissions, water emissions, soil, and marine sediments, noise, waste generation, loss and degradation of terrestrial habitats and changes to marine ecosystems are just some of the main environmental challenges with port's operations.

In recent decades the port industry has experienced extensive growth and technical development. In particular, the container shipping industry is experiencing continuous and sudden growth and development due to urbanization, industrialization and population growth. This not only affects the efficient management of traffic, but also increases the intensity of environmental effects on the marine ecosystem and on the life of coastal communities.

Some research has shown that port authorities and the port industry itself are under increasing pressure to establish their environmental performance and credentials in terms of risk reduction, compliance, and sustainability.

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.

At the same time, some research and studies have suggested that "greener" ports could experience a competitive advantage linked to economic performance and customer retention.

Many ports around the world have implemented "greening" strategies for growth and sustainable development. Among these, European ones are progressing towards better environmental protection and integrated sustainable development through their involvement with local, national and international initiatives (like the EcoPorts initiative by the European Sea Ports Organization). Moreover, it is worth mentioning that also the individual "greening" efforts, understood as efforts made by the port management companies themselves, aimed at the maximum achievement of very advanced ecological standards, have had a recent and flourishing development, especially in the major ports worldwide, where it has become mandatory to adhere to certain environmental standards.

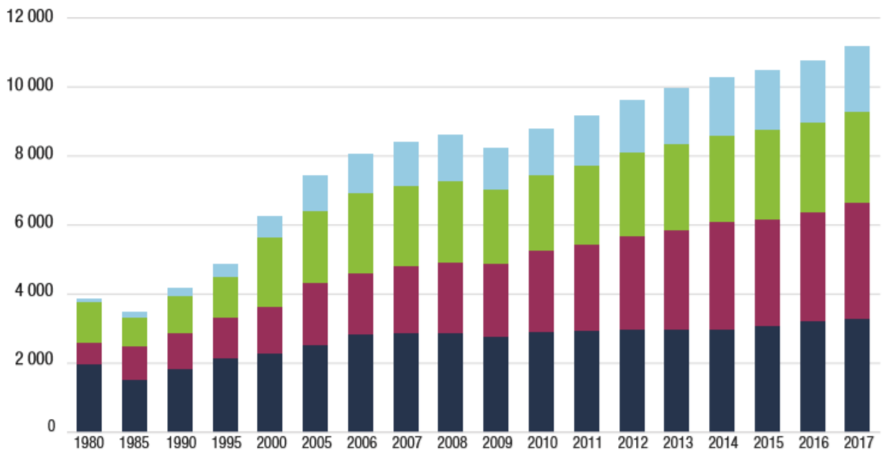
However, although there are ports that work on environmental aspects and the generation of “green ports”, many others have fallen behind in the development of the theme and environmental initiatives are poorly analyzed, with limited scope for identifying best practices. It is precisely for this reason that 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".+

Figure 1.1 *A container dock in the Port of Antwerp during loading and unloading operations (Source: own source)*

2 RELATED CONCEPTS TO MARITIME TRANSPORT

2.1 Shipping growth

The maritime industry contributes billions of dollars to the world economy, creates millions of jobs and continues to expand with the growing demand for transport of consumer products by sea (considering any type of product). Technological progress has continued to improve the efficiency of the sector; according to the documents of the United Nations Conference on Trade and Development (UNCTAD), for the first time worldwide maritime trade has reached 10,7 billion tons in volume in 2017 (Figure 2.1). According to the data reported in Maritime Transport Review 2018, the growth of the world seaborne trade is going to enhance more and more in the next years (forecast until 2023), with a growth forecast of 3.8 % (Figure 2.2).
Having a look at container shipping transport in the figure below (Figure 2.3 and Figure 2.4) is shown the global containerized trade (from 1996 to 2018) and the estimated containerized cargo flows on major East-West container trade routes (from 1995 to 2018). A large increase is reached in the last years until the first part of 2018 (2018a) as it is possible to see in Figure 2.4.



	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Containers	102	152	234	371	598	1 001	1 092	1 215	1 272	1 134	1 291	1 411	1 458	1 532	1 622	1 660	1 734	1 834
Other dry cargo	1 123	819	1 031	1 125	1 928	1 975	2 197	2 232	2 269	2 060	2 087	2 188	2 304	2 392	2 408	2 471	2 459	2 526
Main bulks	608	900	988	1 105	1 295	1 711	1 713	1 840	1 946	2 022	2 259	2 392	2 594	2 761	2 988	2 961	3 041	3 196
Oil and gas	1 871	1 459	1 755	2 050	2 163	2 422	2 698	2 747	2 742	2 642	2 772	2 794	2 841	2 829	2 825	2 932	3 055	3 146

Figure 2.1 *International seaborne trade by millions of tons loaded per year (Source: Maritime Transport Review 2018)*

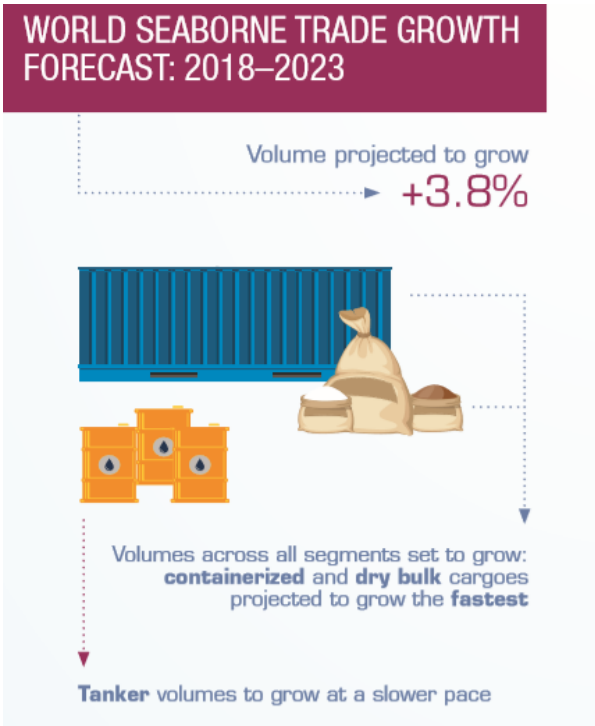


Figure 2.2 *World seaborne trade growth forecast 2018-2023 (Source: Maritime Transport Review 2018)*

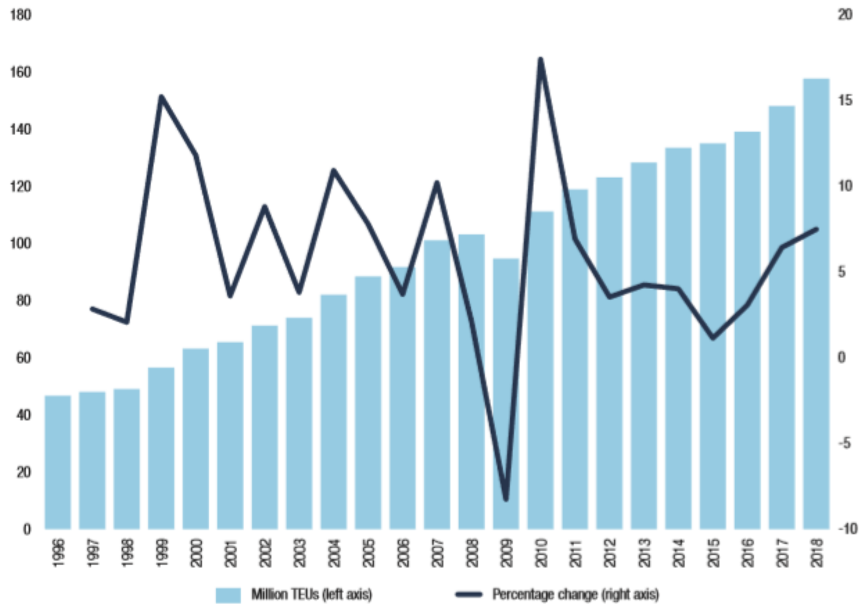


Figure 2.3 *Global containerized trade 1996-2018 (Million 20-foot equivalent units and percentage annual change) (Source: Maritime Transport Review 2018)*

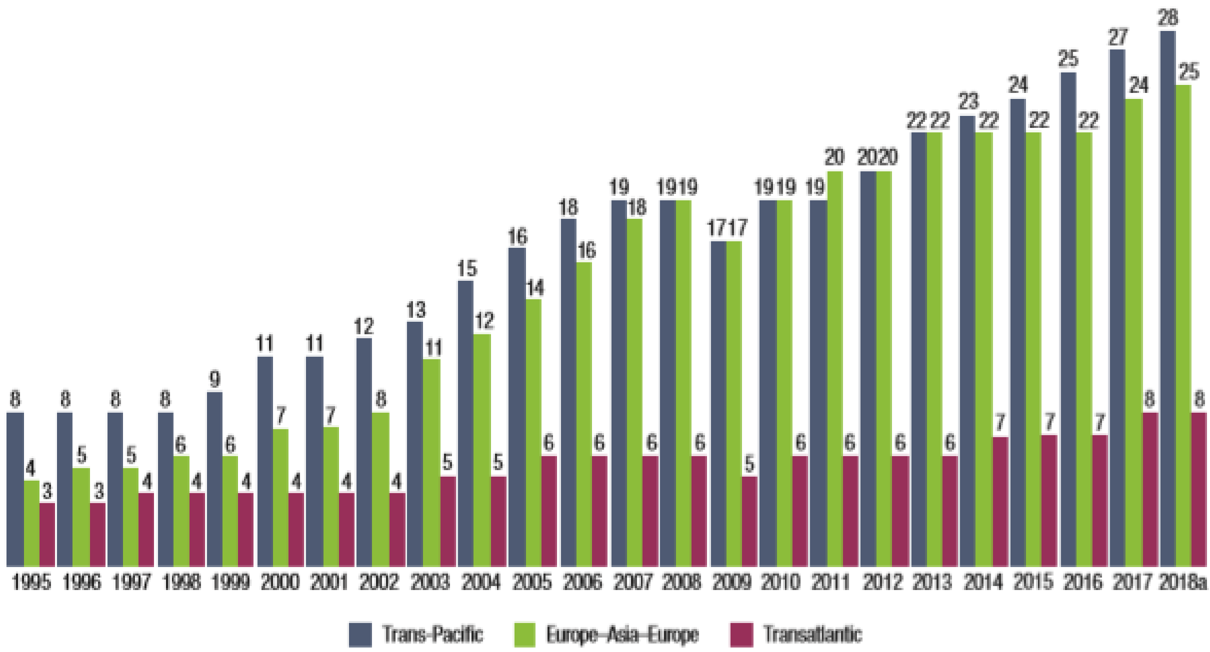


Figure 2.4 *Estimated containerized cargo flows on major East-West container trade routes 1995-2018 by Million 20-foot equivalent units (Source: Maritime Transport Review 2018)*

2.2 Maritime transport and ship evolution

Maritime transport is thought of as the backbone of globalization; as if it acted as a "blood circulation" of the world economy, linking sea corridors to complex transport networks within countries around the world.

It acts as an intermediate mode that connects other modes of transport such as rail, road, and air that allow the movement of passengers and/or goods from one port to another.

In maritime transport, the container industry and the cruise industry are the most successful and the most important ones that grow rapidly.

Leaving aside the passenger sector, which is not of interest for the research carried out, it must be said that instead, the sector of container shipments has registered a much more significant increase in demand.

The global commercial structure, the emergence of new markets, the global division of labour, regional specialization in production and multimodal transport development are factors that have redesigned the maritime container transport sector.

The largest ships in the world are container ships and their capacity has grown considerably over the years, so that the rapid increase in their size has become a controversial topic, as ports are under pressure to cope with increases in length, height and ship's draft.

The following figure shows the current world fleet and the ownerships (Figure 2.5) and the annual growth from 2000 to 2017 (Figure 2.6).

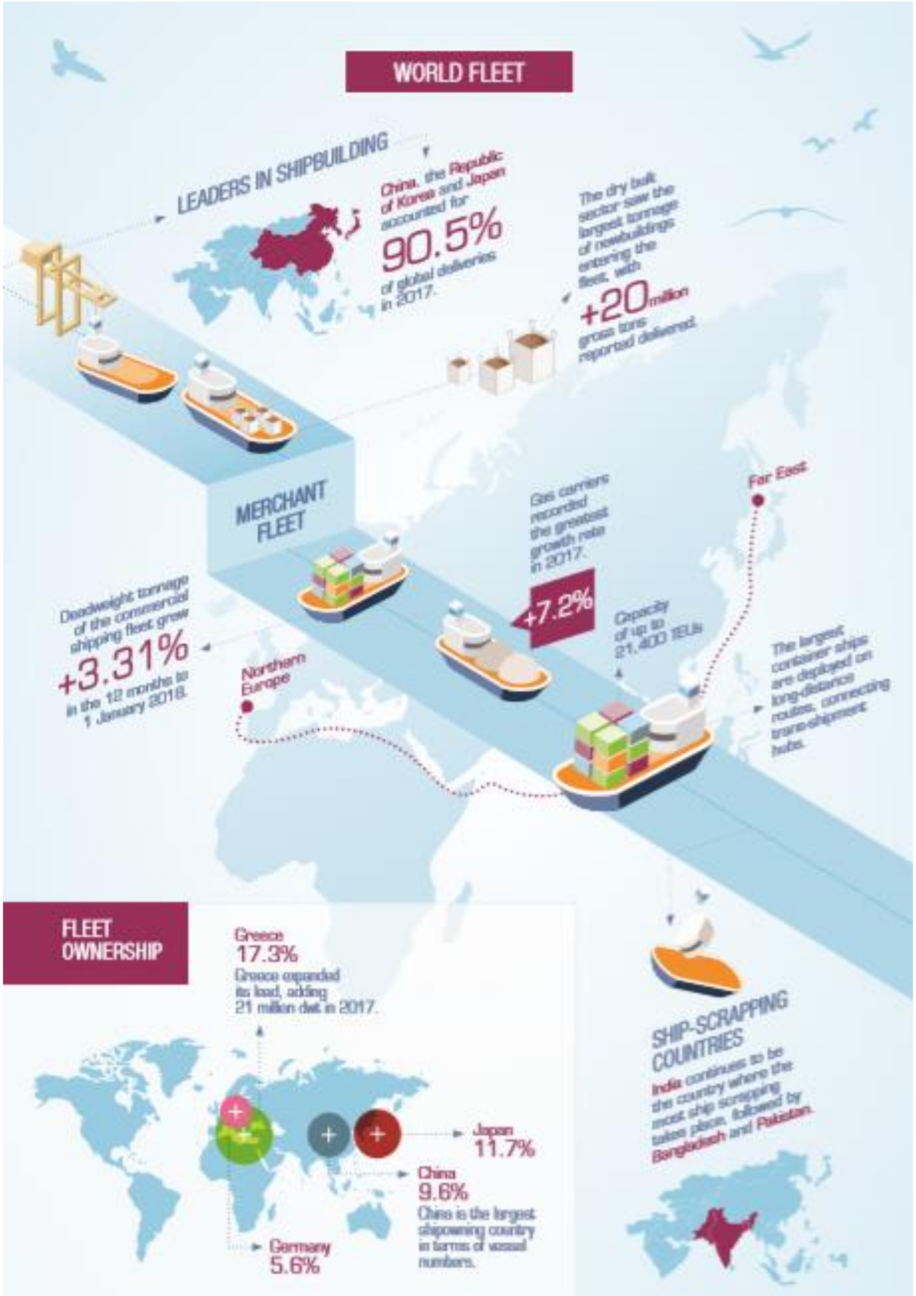


Figure 2.5 *World fleet and ownerships (Source: Maritime Transport Review 2018)*

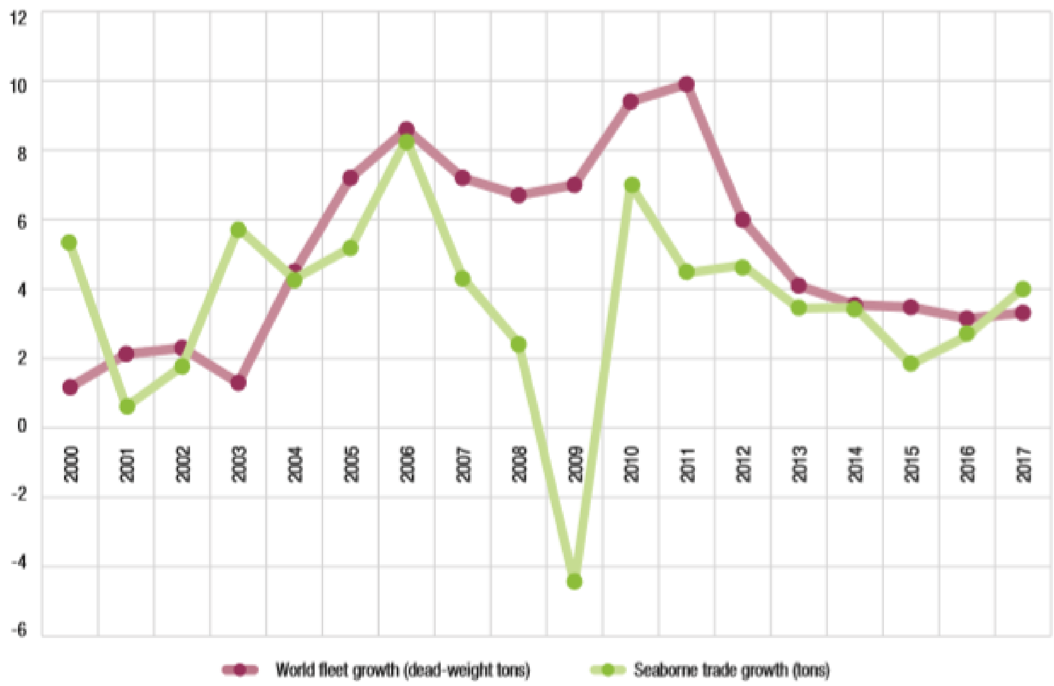


Figure 2.6 *Annual growth of world fleet and seaborne trade in percentage (Source: Maritime Transport Review 2018)*

The world fleet can be also divided into some categories according to the type of vessels, as it is shown in the following figure (Figure 2.7).

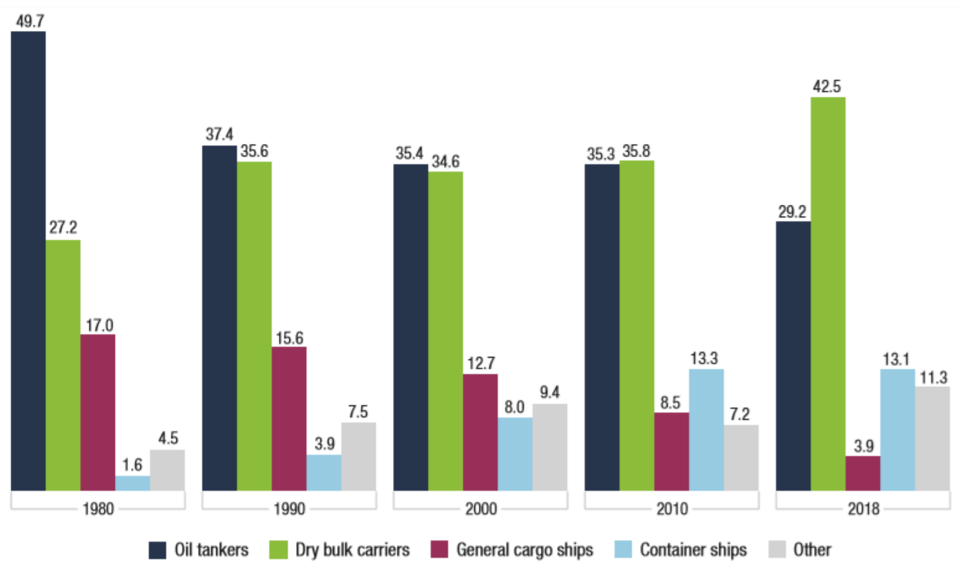


Figure 2.7 *Share of world fleet in dead-weight tonnage by principal vessel type 1980-2018 by percentage (Source: Maritime Transport Review 2018)*

The total length of the current largest container vessel in the world (OOCL Hong Kong) is 400 m with a capacity of 210890 gross tonnage (GT); the largest tanker (class TI) is 380 m long with a capacity of 234006 GT, the largest bulk carrier (Valemax) is 362 m long with a capacity of 200000 GT.

Figure 2.8 shows the evolution of the capacity of a container ship with an equivalent of twenty feet (TEU[1]), since 1968. The increase of the container ship size has accelerated in the last decade.

Between 2017 and the beginning of 2019 more than 40 ships exceeding the capacity of 20000 TEU have entered service all over the world and this is because the intensity of ocean vessel traffic is increasing considerably given the very fast growth in demand.

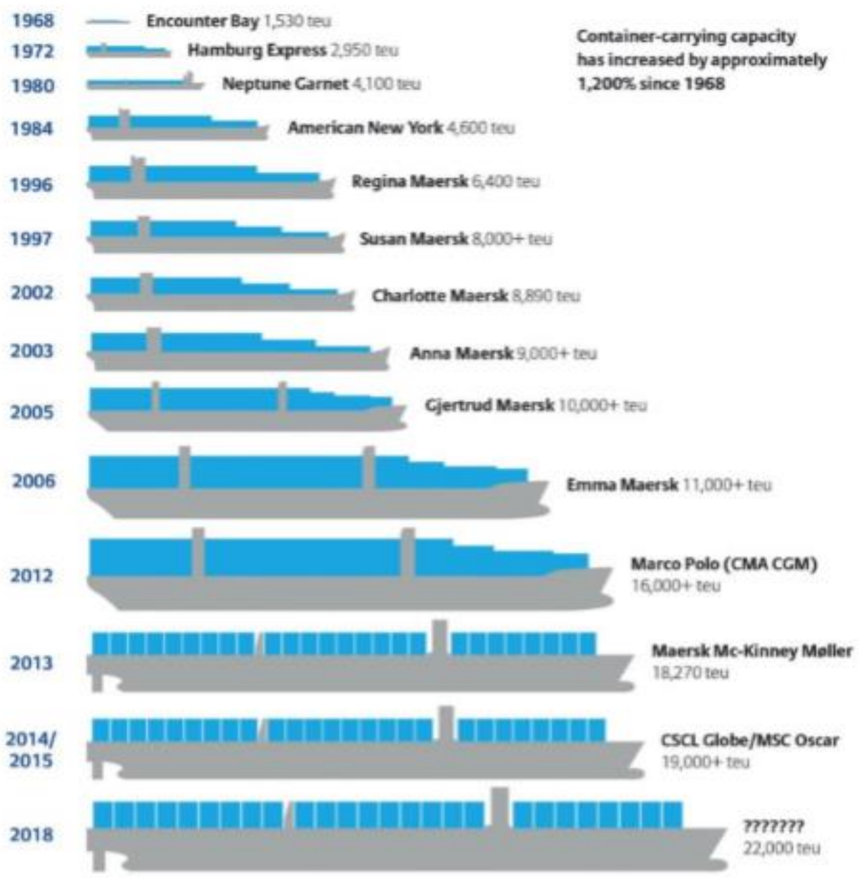


Figure 2.8 *Growth container ship's carrying capacity in TEU since 1968 (Source: Assessment of Sustainability initiatives in port operations: an overview of global and Canadian ports)*

[1] TEU is Twenty Foot Equivalent Unit; unit used to measure container ship's capacity.

2.3 Port operations and relation with sustainability

The ports offer prosperity to the host regions being dynamic trading centers in all respects.
In modern logistics systems, ports are not only the place to load and unload cargo, but also offer value-added services such as storage, packaging, and access to internal transport via other modes of transport by land, and on more occasions are also by air, thanks to the nearby presence of airports suitable for the logistics service.
The commercial competitiveness of a country is influenced by the performance of their ports and terminals; port performance depends on access channels, ease of handling of goods, land and customs efficiency, labour relations and opportunities for terminal operators. Given that this competitiveness of a port affects a country's local and national trade and economy, port authorities have made considerable efforts to increase it and inevitably environmental and ecological progress has been involved.
Ports must also strive to overcome the current social, economic and environmental challenges to which they are subjected. These problems include the increasing size of ships and the cost of adapting port infrastructures, changing the market, constraints on carbon emissions, changes in maritime routes and greater social pressures linked to local environmental impacts such as noise, air pollution, and internal traffic.
Returning to port operations, the activities include:

- transhipment, loading and unloading of cargo to and from ships;
- transfer, boarding and disembarking of passengers and crew;
- storage and storage on land and in stowage to and from ships;
- facilitate access to inland transport and intermodal connections;
- provide other relevant services complementary to the couriers.

Considering what has just been said, the port authorities, in order to ensure that these activities are carried out in an increasingly competitive manner and paying attention to environmental protection, have been activated in different ways.
A first option was to improve relations with regional, national and international organizations linked to ports that can offer indications, support and best practices related to sustainable expansion of the ports themselves.
An important contribution in this regard is made up of those associations that work for cooperation between ports and territorial, environmental and economic organizations. It is the

case then to mention the International Port Association (IAPH) based in Tokyo, a leading authority since 1955. IAPH has 200 member ports, which collectively manage over 80% of the world's container traffic. The European Sea Ports Organization (ESPO) based in Brussels, Belgium, has supported the economic development of European ports since 1993.

As part of its environmental management and sustainability initiatives, ESPO began publishing the "Environmental Code of Conduct" in 1994; this was their first official political document. This code was updated in 2003 and replaced in 2012 by the ESPO Green Guide (published year by year and which was a valuable document for this research).

ESPO also completes periodic environmental surveys in order to study and analyze the performance and the main environmental problems of the ports and the related trends.

2.4 Environmental problems

Ports can affect negative environmental effects at the local level and at a more regional level due to emissions and impacts associated with port activities and operations, maritime traffic and associated intermodal transport.

Figure 2.9 *Top ten environmental priorities by ESPO research (Source: ESPO environmental report 2018)*

Over the years, numerous studies have been carried out that have characterized the most controversial environmental issues associated with port operations. In a recent study conducted by ESPO and EcoPorts, ten environmental priorities have been identified with related motivations and statistical data. These are for European ports (because ESPO has conducted research for ports in Europe), but the concepts could be enlarged to every port in the world. This is possible because every port in the world, more or less, suffers from the same environmental problems, as previous research has established.

A selected set of studies will be discussed in more detail below.

Referring to the figure (Figure 2.9), we can see how the air quality in the port area is one of the main environmental problems linked to the ports. In fact, the world industry of maritime transport represents around 3% of the anthropogenic emissions of greenhouse gases (GHG), and it is expected that this increases more and more with the rapid expansion of the sector. Suffice it to say that if we consider an evolutionary scenario like the current one, it is expected that the greenhouse gas emissions of the ships that will land in the ports will increase by up to 40% in 2030.

Furthermore, Figure 2.9 shows that another major factor is the pollution of the earth, also accompanied by water pollution. Ballast water releases, waste discharges and oil spills all contribute to the degraded quality of a port's water.

Waste management is also clearly involved, despite the fact that it is improving thanks to the very stringent IMO regulations mostly explained in MARPOL (International Convention for the Prevention of Pollution from Ships).

Noise is another important factor. It derives not only from port operations but also from auxiliary activities such as industrial activities (within the port) and other services.

The port's environmental performance has become an integral part of the port authority's corporate responsibility following the competitive pressure of regulatory agencies, local communities, NGOs, port users and other interested parties.

2.5 Role of the ports

Ports have a specific responsibility towards the surrounding biophysical environment and the host communities to create opportunities in more sustainable and more ecological activities.

We must guarantee safety in operations, social, ethical and environmental responsibility.

The port authorities, the first bodies responsible for ensuring all of the above, can apply a wide range of political instruments, not only to manage the environmental effects of operations in port areas.

Energy management in port areas is a potential measure to reduce emissions into the atmosphere.

Ports can play a significant role in energy management as they have a high energy requirement and have power generation facilities.

There is a huge energy demand for direct activities (for example, terminal operations, buoys, lighting and administrative buildings), for powering ships calling at the port and for activities related to the port (for example, railway operations, refineries, steel mills and metallurgists, etc.). Ports can be proactive on the efficient use of energy and on the promotion of energy management (for example, the port of Hamburg in Germany), and can also contribute to the promotion of renewable energy use and increase energy efficiency through the plan of energy management.

Onshore Power Supply (OPS), the supply of alternative fuels such as liquefied natural gas (LNG) and liquefied petroleum gas (LPG) and the development of biofuels are some structures of other ports that contribute to both energy management and emissions reduction in port areas.

2.6 Environmental management in ports

The main purpose of the environmental management of the port is still to mitigate the negative effects.

While some ports adopt environmental management initiatives for regulatory compliance, others go beyond compliance with an emphasis on improving their performance in environmental management and achieving port sustainability.

Europe, in particular, has significantly developed environmental management over the last fifteen years thanks to the mutual collaboration between ports, research institutes and specialized organizations such as the first ESPO.

An effective port environmental management system requires that the environmental components of interest be identified in advance, so as to be able to determine what can be managed from an ecological perspective. There are tools to identify significant environmental components and to identify the relevant performance indicators. It will be possible to see a slight application of what has been described up to now in the final phase of this research in which the attention will be focused on the management measures to be adopted based on the results of the analysis carried out.

The adoption of environmental performance indicators (EPI) offers benefits to ports, enabling progress to be monitored, illustrating trends over time and measuring the effectiveness of environmental management activities.

Several environmental monitoring tools such as the Self Diagnosis Method (SDM) and the Port Environmental Review System (PERS) have been developed by ESPO with the aim of providing ports with an efficient methodology to identify environmental risk, establish priorities for the environment. action and compliance for port operations and provide a specific environmental management standard for the sector.

These tools consist of their own descriptive structure of the environmental parameters and of the numerical indicators associated with them in order to provide a valid means of analysis.

There are also other tools known as PORTOPIA (Port Observatory for Performance Indicator Analysis) and GMEP (Green Marine Environmental Program).

Although ports are becoming increasingly aware of the benefits of using such analytical tools that involve environmental indicators, there is no common approach on which indicators to adopt.

Therefore, research is still needed in this field.

The work reported here, therefore, in part, aims to identify and select the main environmental performance indicators (EPI) for sustainable port development. Through a discrete choice analysis (DCA) it was possible to find a classification of these indicators by going to study the prevention measures.

3 CONCEPTS AND CRITERIA ABOUT GREEN PORTS

3.1 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. In these publications, it is also suggested that green ports work to balance economic demand with environmental responsibility through research and innovation.

The concept of sustainability considers social, economic and environmental issues.

Thanks to various studies on the subject, a combined framework has been implemented, including elements such as stakeholder participation, green market development and an economically efficient environmental policy with the green port's strategy.

The concept of the green port is more restricted than the concept of sustainable development.

The exact definition of sustainable development is: *"sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their needs"* (Brundtland Report 1987 called "Our Common Future" issued by United Nations World Commission on Environment and Development), we can talk about sustainable development when there is a port development that meets the needs of the current generation and at the same time respects the needs of future generations.

The maritime industry has been considered a significant support for economic development for over 300 years and the introduction of containerization has significantly altered the connections between players in the freight transport chain.

Containerized trade has dramatically increased in volume over time since container boxes were introduced for delivery in 1956 (by the inventor Malcolm McLean).

Because of this, ports around the world are now growing at an exceptional rate and their performance does not only consider their production and efficiency, but also their ecological performance.

3.2 Opportunities for green and sustainable ports

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 for which they proceed in this field:

- obtain or improve their social license to operate;
- improve their corporate conscience;
- increase and improve their competitive advantage (cost reduction, efficiency, etc.).

Most of these initiatives gave the opportunity to observe that the adoption of environmental management programs and ecological commercial strategies bring better environmental performance and solid competitiveness. Value-added services for environmental management can bring direct and indirect benefits to port cities. Value-added services (e.g. industrial development, coastal development and port facilities) and port activities have direct impacts that create jobs and income and have indirect impacts generated by port services and the supply of goods that bring productivity, growth and economic attractiveness for ports.

In various studies conducted in this field, ports have been seen as platforms for circulation and conversion of material and energy flows and could be interesting laboratories for the implementation of a concept known as industrial ecology. 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.

3.3 Perceived challenges

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;
- volatile energy prices;
- the transition to alternative fuels;
- stricter limits on sulfur emissions.

Many port authorities today are facing the challenge of contributing to greater international competitiveness and better environmental performance. In a study conducted by the ESPO in more than 120 ports of EU Member States, more than 70% of the ports encountered some difficulties in adopting environmental management measures. The main challenges faced by ports in implementing environmental management are:

- search for interested parties / competent authorities involved;
- the cost of environmental management measures;
- lack of knowledge in the implementation of good environmental management practices.

Thanks to the results produced by research in this field, the cost of implementing environmental management measures and the lack of data has been the binding forces for sustainable development in many ports.

Some researchers believe that the regulations and pressures of the community sometimes hinder the development of the ports because the ports must respect the regulations and satisfy the expectations of the society.

Furthermore, port operations are now increasingly hampered due to the impacts of climate change.

Port authorities must identify and assess the risks of climate change-induced effects on port infrastructure and operations and must collaborate with the scientific community, policy makers, government and other stakeholders to formulate and implement proactive adaptation measures to the end to make ports resilient to extreme weather events.

In the research addressed here, it must be 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 should be considered:

- do 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.

The basic 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, economic and efficient resources, good ecological attributes 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. It needs a coordinated distribution in several phases, a secondary focus within our capabilities, considering both the economic advantage and long-term development.

By applying the notion of building green ports in port planning, reasonable port development policies can be proposed from the point of view of the environment and resources, 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 combine 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.

3.4 Green objectives

For the construction of a green port, research was carried out on some strategic objectives that analyze the main functions of Port Authority and focus on how environmental sustainability interferes with each function of the main port authority.

3.4.1 Landlord function

The main strategic objective related to the landlord function, as reported in the following table (Table 3.1), is to manage the areas and activities entrusted to the port authority.

Green Objectives Landlord Function
Protect the port ecosystems
Ensure environmental sustainability of the economic activities linked to the port
Create optimal space allocation and green recreational areas
Include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet
Provide adequate waste reception facilities
Attention for sustainable construction methods when building infrastructure
Ensure the use of space is optimized in master planning
Include environmental considerations in the planning and execution of connectivity policy and infrastructure
Adaption to climate change

Table 3.1 *Landlord function (Source: Environmental sustainability in seaports: a framework for successful innovation)*

More in detail we talk about management, maintenance and development of port assets, provision of port infrastructures and facilities, design and implementation of development policies and strategies related to the exploitation of heritage.

3.4.2 Regulatory function

Port authorities aim to regulate activities within the port with control, surveillance and police functions. This is to ensure safety within the port, but also a form of environmental protection (Table 3.2).

Green Objectives Regulatory Function
Regulate environmental matters within the port
Implement national/regional/global environment regulation
Monitor pollution, including noise and emissions
Allow/prohibit activities within the port
Reward/punish port operators over/under performing against specific environmental goals
Share information with reference to environmental compliance

Table 3.2 *Regulatory function (Source: Environmental sustainability in seaports: a framework for successful innovation)*

3.4.3 Operation function

The operator's function considers all the activities carried out in the context of managing the activities within the port for profit (Table 3.3).

Green Objectives Operation Function
Minimize impacts from operations
Improve energy efficiency and energy conservation within the ports
Ensure operators include environmental considerations in the selection and management of subcontractors

Table 3.3 *Operation function (Source: Environmental sustainability in seaports: a framework for successful innovation)*

3.4.4 Community function

As a community manager, the port's main purpose is to manage stakeholder relationships and manage the port community, structuring the port community and strengthening connections between the city and the port (Table 3.4):

Green Objectives Community Function
Share information and increase the visibility of green activities
Ensure coordination of environmental activities
Market the port as green
Ensure environmental awareness among employees of both the port authority and the port operators
Simulate and facilitate port users in adopting green practices
Sustainable resource management

Table 3.4 *Community function (Source: Environmental sustainability in seaports: a framework for successful innovation)*

3.5 Green and Smart ports: two inextricable concepts

In the discussion of this chapter, the concept of integration between green port and smart port emerged without having been made explicit. These are two totally inextricable concepts.
Green ports and smart ports will be integrated into operations and developments. Green ports and smart ports are inseparable.
A port should consider the development of a green port as its main objective and assume the mode of development of the smart ports as the main technical medium.
The ecological development of the port is the main objective of low energy consumption, low emissions and low pollution, as widely repeated; while the development of the smart port is based on smart technology (innovative technology of a certain calibre) to improve the efficiency and competitiveness of the port operation.

The green development of the port requires the support of port intelligence and technological innovation and green development is also and above all an important concept in developing smart port.

Without the concept of sustainable development and green port, the way to obtain a smart port would hardly be realized.

In general, therefore, green development is an important concept of smart port.

At the same time, the application of smart port technological innovation is the key means to reach the goal of a green port.

A green and smart port is an entire organic system and at this point we can absolutely say that the development of the integration of green and smart ports will be an inevitable way to achieve sustainable port development in the future.

To build a more scientific and systematic framework of governance for green and smart ports, academic research has been developed that outlined some practical features found in the following table (Table 3.5):

	Dimension	**Description**
Green and Smart port	*Greenness*	Industrial and production modes with high technology content, low resource consumption and less environmental pollution
	Agility	Working methods guided by a quick and efficient methodology subject to constant reforms
	Personalization	New production models that are able to meet unique market requirements in the new market environment
	Cooperation	Strengthened international cooperation, enhanced port-city integration and

		increased cooperation with inland ports
	Intelligence	More modern smart technologies integrated into port working environments to improve port operation levels
	Liberalization	Relaxed government regulation to give full play to the role of market mechanism to facilitate trade

Table 3.5 *The development concept for green and smart ports (Source: Constructing governance framework of a green and smart port)*

The concept of ecology includes four factors:

- energy savings and emission reduction capacity;
- pollution treatment capacity;
- effective use of resources;
- concept of environmental protection and political system.

Agility covers three factors:

- agile production capacity;
- complete logistics capacity;
- optimized operational capacity.

Customization includes differentiated service levels:

- at the port level (personalized service levels for customers);
- capacity for rapid and emergency response.

Cooperation includes:

- the international freight forwarder;
- integration between port and city;
- cooperation between residents and sports.

Intelligence refers to the following components:

- infrastructure and intelligent production operations;
- intelligent administration;

- the security of intelligent structures;
- innovative research and development and technology applications.

Liberalization includes:

- the liberalization of economic and commercial policies;
- facilitation of logistics and customs clearance;
- the opening of investments and financing.

From Figure 3.1 it is possible to understand the relation between the green and smart port:

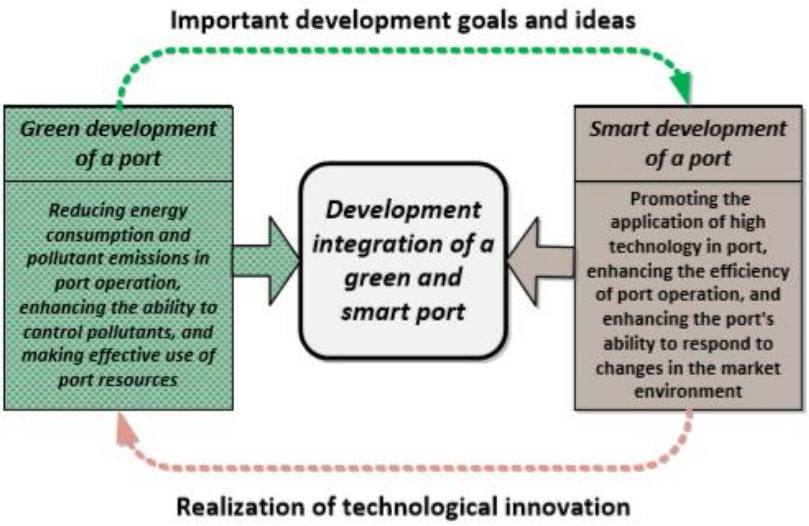


Figure 3.1 *Concept map of a green and intelligent port integration (Source: Constructing governance framework of a green and smart port)*

3.6 Port Sustainability Indicators (PSI)

It is believed that having a way of measuring the sustainability of a port through indicators (PSI Port Sustainability Indicators), which manage to outline and identify their meaning, is fundamental. However, these are non-categorical indicators. They only work as an interpretative guideline of the concept and can be modified according to the situations faced and the case studies examined.

The PSI can also be a solid basis for measuring, monitoring and improving the concept of port sustainability, as well as defining it only.

Table 3.6 shows the main characteristics that these indicators should have. They are going to be discussed deeper in the following chapters.

Characteristics
Representativeness
Conciseness
Purpose
Usefulness
Relevance
Adaptability
Comparability
Sensitivity
Clarity
Reliability and objectivity
Easiness to obtain
Continuity
Regularity
Scientific verification
Presence of well-defined limits
Cost-effectiveness

Table 3.6 *General characteristics of port sustainability indicators (Source: Assessment of port sustainability indicators in the sustainability reporting process)*

Sustainability indicators are not universal but are useful both for measuring current progress and for identifying current problems.

From some analyses conducted at an academic level, it has come to understand that the use of PSI is of considerable importance to understand how a port can be more performing than another. Therefore, at the base of this simple concept, this study carried out here aims to propose a series of indicators of port sustainability (as it will be possible to see in the next chapters) and thanks to these go to study how the performance of a port (in terms of sustainability clearly) go to influence the behaviour of a ship or more precisely of a container shipping company.

3.7 Green ports regulation

Port strategy and regulatory subjects, in particular the practices of approach to safety and environmental safety, have been one of the most important topics of port studies in recent years. Furthermore, policy-makers are commonly interested in the global port operation covering environmental aspects. Not only political decision makers like governments, international or national organizations are enthusiastic about ecological environmental regulations, but also container shipping companies such as ports and shipowners are very interested in making their companies or organizations environmental friendly.

Likewise, container shipping companies looking towards their internal green practices are taking steps towards an ecological policy, ecological transport, and green promotion, working collectively towards environmental development.

Figure 3.2 shows the development of international legislation on the green port over the past 50 years.

It illustrates how the laws relating to environmental sustainability (green) were formulated.

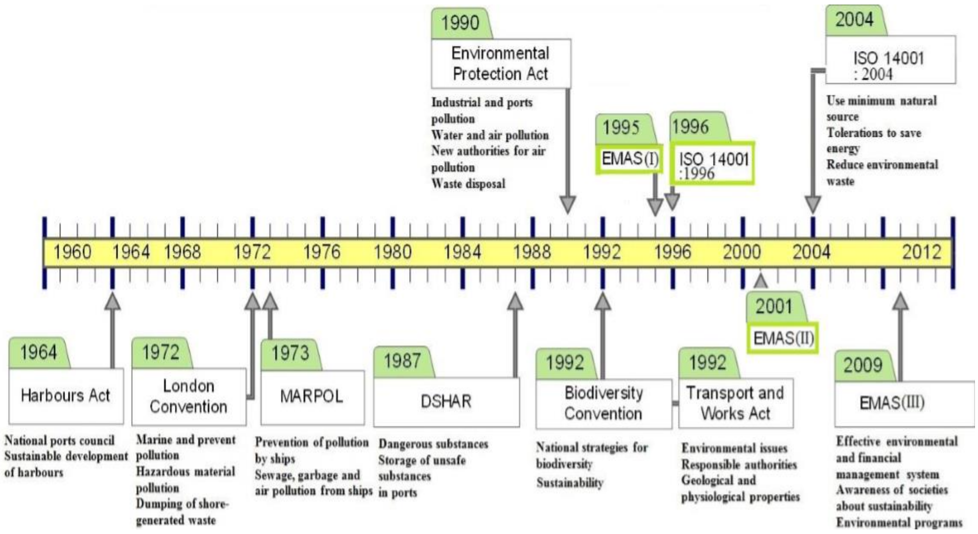


***Figure 3.2** Timeline of legislation about green port (Source: Sustainable port operation management: green performance criteria for container terminals)*

The first legislation was the law on ports, published in 1964. It had three main purposes which consisted in the implementation of the development of the control port and in the assistance of the salary for the execution of port works. In addition, it has organized supplies for the sustainable development of the port and management.

The second law was the London Convention, published in 1972.

It was an agreement on the prevention of marine pollution caused by the discharge of waste.

It was concerned about the control of all sources of marine pollution and to prevent international sea pollution by regulating the discharge of waste materials into the sea, such as blocking some hazardous materials.

Subsequently, MARPOL 1973/78 was inserted one of the related conventions.

In addition, the fourth convention (in 1987) concerned dangerous substances in port zone regulations (DSHAR), which had been foreseen for transport management, loading, unloading and storage of hazardous substances in ports.

In 1990 the Environmental Protection Act (EPA) was published.

According to EPA (2007), the regulation has created provisions for better control of pollution from certain industrial and other processes such as ports and to dispose of waste from land, water and air.

The EPA has also created an integrated waste control and has provided local authorities with air pollution management from various prescribed processes. In addition, it developed waste disposal instructions.

The next convention was in 1992 concerned the Biodiversity Convention (CBD).

It stated that the CBD was a convention to develop internal strategies for the protection and use of biodiversity for sustainability.

The universal structure of the convention provided for industrialized countries to obtain mutual benefits for their economies and for the sustainable use of its components and the fair and equitable sharing of benefits.

Later, in the same year, legislation was published regarding the law on transport and works, connected to green ports. Furthermore, according to the Ports Act of 1964, this legislation highlighted environmental issues in port driving and attributed responsibilities to port authorities in this regard.

It promotes the protection of the importance of rural and natural beauty, and to protect geological and physiological properties towards ports under the laws.

Thus, the EU Eco-management and Audit System (EMAS) is the latest system that helps the environmental aspect of container ports to become effective in 1995 and was strengthened in 2001 and 2009.

EMAS helps organizations to increase their environmental and financial performance to use the environmental management system as a tool. It develops its environmental performance and an environmental aspect is defined as "an element of the activities, products or services of an organization that can interact with the environment".

Finally, ISO 14001 Environmental Management System (EMS) is widely accepted as the most important international environmental management standards published in 2004 with an earlier version published in 1996.

It is one of the main elements concerning the minimization of the use of natural resources and adverse changes to air, water or land from operations.

According to some research conducted, the EMS is a real indispensable element for pursuing the objectives listed below:

- improve compliance with national and international legislation and environmental legislation;
- tolerate companies to increase their compliance with existing national acts;
- progressing and implementing environmental management regimes to improve price control and energy management;
- work to reduce and manage toxic waste from the beginning of the process;
- prepare energy savings and use resources efficiently;
- take measures to reduce environmental waste.

4 CASE OF STUDY AND METHODOLOGY

4.1 Problem definition of the case of study

As seen up to now in the previous chapters, pursuing environmental strategies that lead to the creation of a green port is the basis of ecological problems in the world of maritime transport.
The work that has been done in these 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) and it is therefore that, 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 shipping company when deciding its approach to a port.
A discrete choice experiment makes it possible to attribute an importance value (for the most part we speak 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.
Once the importance of these criteria has been established, it is possible to proceed with appropriate actions and measures in order to improve them in every aspect.
To define the discrete choice analysis, it is important to determine what the alternatives would be in the survey that will be conducted to highlight the criteria just discussed. Since this research has the purpose, as mentioned, of facing, by a shipping container company, the choice of ports based on the factors that contribute or not to make the port a green port, such alternatives would be just the ports.
As will be described later, two generic port alternatives will be considered, which will be called Port A and Port B.
The problem will be addressed with the following schematic approach. The phases collected in this graph will be described in detail below, considering that they represent the most correct methodology to follow to identify the relative importance of the factors of choice of a green port by a shipping container shipping company.

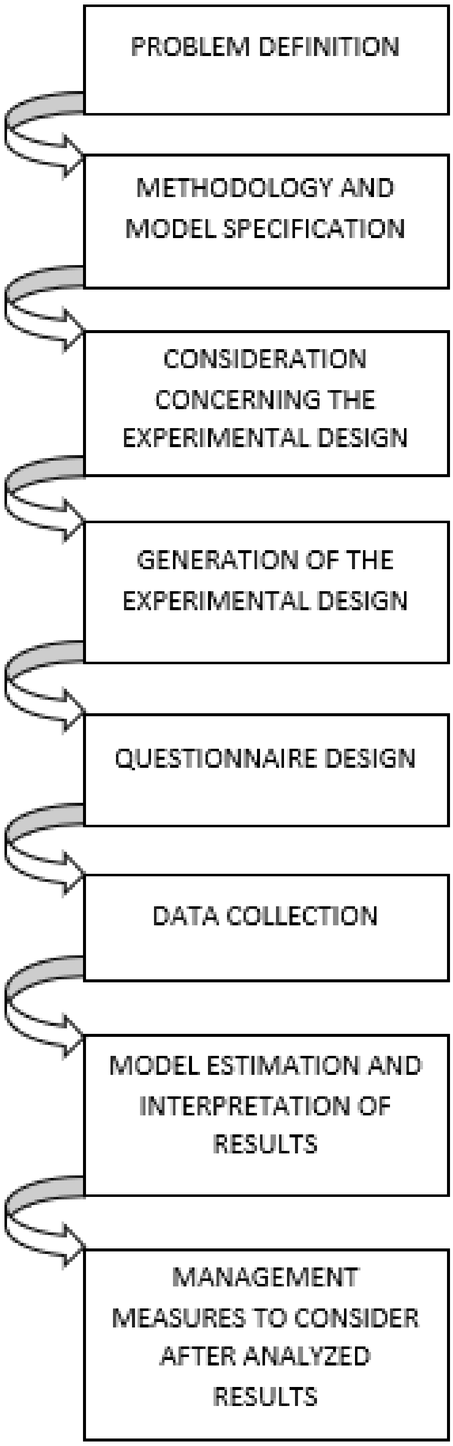


Figure 4.1 *Scheme of the phases of the research (Source: own composition)*

4.2 Methodology of Discrete Choice Analysis (DCA): what is and what it needs

Before going on to define the methodology and the specifics of the work model with which this research was carried out, it would be better to talk more depth about the concept of discrete choice analysis, specifying what an experiment of this type is, what it needs, what supports and how it is actually performed.

Discrete choice analysis is often seen as a special case of conjoint analysis and therefore often called "choice-based conjoint analysis".

However, as will be described below, both the conjoint analysis method and the discrete choice analysis method have significantly different theoretical principles.

Conjoint analysis based on choice is often interchangeable with discrete choice analysis.

In a conjoint analysis (rank-order conjoint analysis) the interviewee is presented with all the alternatives and is asked to order them based on their preference. The advantage of this type of approach is that the respondent will have to consider all the options simultaneously.

However, to be able to translate the ranking into actual choices, it must be assumed that the interviewee is perfectly consistent with his position, that he has perfect information on all the alternatives, that he lacks constraints (like a budget) and prefers always one of the alternatives. For the respondent to be able to perform the ranking, the number of options must also be limited. Another disadvantage is that, with this approach, the interviewee judges the different options but in reality, does not choose between them as in real life.

This latter disadvantage also applies to the conjoint analysis of the rating scale (rating-scale conjoint analysis). Here the respondent must evaluate different options based on his preference; in most cases an assessment must be made per couple. The preference can, therefore, be indicated with a sort of score.

Another approach to conjoint analysis is often indicated by conjoint choice-based analysis (choice-based conjoint analysis).

In this approach, the interviewees choose between two or more alternatives.

In the following figure the link between the conjoint analysis and the conjoint choice-based analysis is shown with a dotted line; this means that it is a very particular case of conjoint analysis, indeed it is actually a process, better known to us as a discrete choice analysis (DCA) which has other theoretical bases than the actual conjoint analysis.

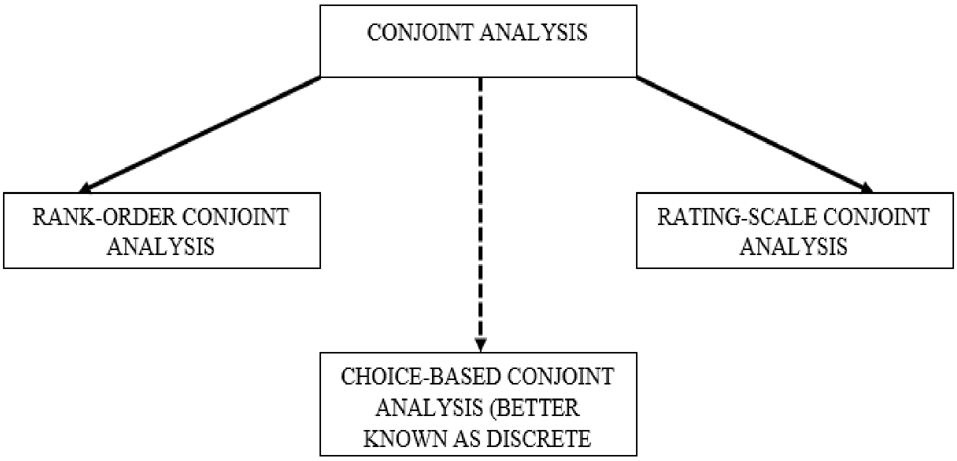


Figure 4.2 *Conjoint Analysis division (Source: own composition)*

The discrete choice methodology is today the most widespread, as it has a comparative advantage in terms of less cognitive complexity for the respondent and estimation for the researcher. Recently, the attention of the economic evaluation studies has turned to the family of methodologies deriving from the multi-attributes' "conjoint" analysis, which are united by the following characteristics:

- the asset to be valued is disaggregated into several attributes and levels;
- the choice made to the person concerned is between different alternative offer scenarios (contingents) characterized by different levels of attributes;
- the analysis is based on repeated choices made on choice nuclei composed of at least two alternatives, from which the data necessary for the estimates of the answers are obtained.

The discrete choice analysis system tends to examine the products analyzed describing them as sets of different attributes that vary on different levels. In other words, different groups or sets of choice are presented to the interviewees, consisting of several alternatives defined on different levels of the relevant attributes of the product in question. For each set of choice, the interviewee must select the most preferred option or choose none of those proposed.

Econometric models are then used to estimate the relative importance of the different attributes in the consumer choice process or the willingness to pay for a specific attribute, but this will not be the subject of this study.

The main advantage offered by the experiments of choice consists in simulating the real mental process followed by the consumer during the purchase phase.

Indeed, the interviewee evaluates the product, without having to express its preferences separately for each individual feature of the product under examination, as implicitly hypothesized by the simpler and more traditional approaches.

Discrete choice experiments were initially developed by Louviere and Hensher[2] (1982). Their first application in the context of natural resources is attributed to Adamowicz, Louviere[3] (1994). This methodology is a relatively new technique, born in the 1980s to overcome the limitations encountered in applying the normal conjoint analysis techniques in the transport and telecommunications sector.

In fact, the normal techniques of conjoint analysis, which consist in asking the consumer to assign a score (rating) or an order of preference (ranking) to the products in question, raised doubts among economists and marketing experts, due to practical difficulties and theory related to the collection of preference data.

These uncertainties concern the difficulty of being able to make interpersonal comparisons using ranking or rating data, the difficulty for respondents to assign an order of preference when there is a large number of alternatives and poor adherence, in particular to the rating technique, to the real purchase decision. The consumer, in the face of different types of a given product, assigns neither points nor an order of preference, but after having compared the characteristics of the various possible choices, he decides which one, in his opinion, is the best, without giving an order to the other.

Discrete choice analysis seems to be the most promising approach to address the problem defined at the beginning of this chapter in the most correct way.

The discrete choice analysis allows the researcher to receive information on the value that the interviewees attribute to a certain factor or more generally to a good or service and also with this method the trade-offs are also brought into play, before which they are places the generic interviewees or, as in our case, some companies.

[2] Authors of an article in published 1982 on Journal of Consumer Research; title was "Using Discrete Choice Models with Experimental Design Data to Forecast Consumer Demand for a Unique Cultural Event".

[3] Authors of an article published 1994 on Journal of Environmental Economics and Management; title was "Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities".

4.3 Differences between discrete choice analysis and conjoint analysis

Nowadays, the term "conjoint analysis" is often used for all methods of soliciting preferences that involve certain variations in attributes and levels. Furthermore, many researchers refer to the analysis of discrete choice as a conjoint analysis based on choice, and therefore a special case of conjoint analysis. However, both methods have very different underlying axioms. The conjoint analysis, on the one hand, derives from the theory of conjoint measures which is purely mathematical and does not concern the behaviour of humans or choice. In conjoint measurement theory, it can be shown that people use a certain mathematical process "as if" to combine the preferences for each level of an attribute into a preference for the alternative thus obtaining a classification or evaluation of alternatives.

Furthermore, the conjoint analysis is not consistent with utility theory in that the data is collected in a way that cannot be easily translated into a choice.

The theory of discrete choice analysis, on the other hand, is a theory based on the behaviour of choice by the respondent. Here, the behavioural process with making choices is central.

Furthermore, the theory of discrete choice 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 a service can be observed by the analyst. Therefore, the overall utility of a product or service is seen and therefore also written as a composition of observed attributes and unobserved utility sources. This is explained by the following equation 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:

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

All this is based on the so-called “Consumer Theory”[4], according to which it is possible to break down the usefulness of a given product/service into many utilities related to the individual

[4] Consumer theory is the study of how people decide to spend their money, given their preferences and budget constraints. A branch of microeconomics, consumer theory shows how individuals make choices, given restrains, such as their income and the prices of goods and services. Through consumer theory, we are better able to understand how individuals’ tastes and incomes influence the demand curve. These choices are among the most critical factors, shaping the overall economy.

characteristics or attributes of the product/service itself, and on the "Random Utility Theory"[5]. In that formula:

- 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 nth consumer as well as by the characteristics of the attributes of the i-th selected good / service;
- ϵ_{ij} represents that 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.

The theoretical foundation of the methodology is represented not only by utility theory, but also by the microeconomic theory of choice, which holds that everyone has a preference relationship between the possible alternatives of choice.

The representability of the structure of individual preferences through the mathematical function U (utility function).

Let us consider two alternatives *y* and *j* (which can represent goods or services, indifferently) belonging to a specific choice set, i.e. a set containing some of the available product or service alternatives to which the individual is called to express his preference. The consumer, whose action is presumed to be dictated by reason, I will be led to select those alternatives that will guarantee him to reach the maximum possible utility. Starting from this assumption and as assumed by the Random Utility Theory, the probability that a given product is preferred over the other alternatives available is greater than the value of the "U utility function" [6].

The concept of casual utility, used in the economic field for the development of numerous econometric models, provides for an interpretation of the same as a latent concept, that is, existing in the mind of the consumer and not directly observable, in all respects, by the analyst.

[5] Random utility theory is not an accurate description of human behaviour. Nevertheless, checking that models of behaviour are consistent with random utility theory provides is a way of checking that the models do not have silly and inconsistent assumptions.

[6] In economics, utility function is an important concept that measures preferences over a set of goods and services. Economists create a parametric functional form for the utility based on the assumption of observed consumer behaviour, with a number of goods as variables and certain fixed parameters.

In support of researchers, however, a theory of probabilistic choice has been introduced, which states, as was also described above, that the consumer, in an attempt to maximize his utility, acts in a completely probabilistic way, recognizing the inability for researchers to identify all the aspects that influence their choice.

Discrete choice experiments originate from an initial study where the responses of single individuals to different levels of psychological stimuli were analyzed. Subsequently, they began to interpret these stimuli as a utility, and it was precisely from this that a derivation of the utility maximization function previously seen came to be provided (sum of an observable and an unobservable component).

At the theoretical level, it can be stated that each individual, in making his choice, will promote the alternative j if the relative utility U_{ij}associated with it is superior to the relative utilities associated with all the other available options. The presence of stochastic components involves a probabilistic type structure for the reference model.

If the choice of the *i-th* consumer depends on the additional utility (Z_i) that derives from the purchase of the product *j* with respect to the product *n*, the latter can be expressed as follows:

$$Z_i = U_{ij} - U_{in} = \left(V_{ij} + \epsilon_{ij}\right) - (V_{in} + \epsilon_{in}) = \left(V_{ij} - V_{in}\right) + (\epsilon_{ij} - \epsilon_{in})$$

The variable Z_i is commonly defined as the latent variable of the model. The idea behind the concept of latent variable is that there is an implicit propensity to purchase that generates the observed state (the purchase or not of the product *j* by the *i-th* consumer).

While it is not possible to directly observeZ_i, a change of the value of Z_i to a given point or value of the same variable determines a change of the observed state, more precisely the propensity exceeds a certain limit that is assumed to be equal to zero, determining the purchase of good *j*.

The *i-th* consumer will, therefore, be inclined to purchase the good *j* if Z_i is greater than zero, and not inclined in the case where Z_i is negative or equal to zero. In the first case the dependent variable Y_i will assume a value equal to 1, in the opposite case value 0.

$$Y_i = 0 \text{ if } Z_i \leq 0$$

$$Y_i = 1 \text{ if } Z_i > 0$$

Given that the portion $\epsilon_i = \epsilon_{ij} - \epsilon_{in}$ in of the actually perceived utility is not observable, this is considered random with a density function $f(\varepsilon)$.

The models that can be derived in this way are commonly referred to as random utility models. In particular, it is possible to provide a definition of the probability of choosing an *i-th* alternative good/service, by an *n-th* consumer, to the detriment of the other alternatives present within a given choice set, as follows:

$$P(i|C_n) = P(U_{in} \geq U_{jn}, \forall j \in C_n)$$

According to this formula the probability, for the *n-th* consumer, of selecting the *i* option within a choice set (a choice set C_n) is equal to the probability that the sum of the representative and stochastic vector components of the *i-th* alternative is greater than the sum of the vector components of each of the *j* alternatives present in the choice set C_n.

To sum up, conjoint analysis is more than a mathematical method, while discrete choice analysis is based on behavioural theory.

While the analysis of discrete choice seeks to model the entire decision-making process and can consider the different stages of the process, the conjoint analysis focuses only on one level of the process.

Furthermore, while in the discrete choice theory the properties of the error components play a significant role, in the conjoint analysis the components of the error lack a clear interpretation. Therefore, the approach based on discrete choice seems to be the best starting point for our study.

Last, but not least, the discrete choice approach seems to be a more realistic approach than conjoint analysis in that respondents not only classify or evaluate alternatives but make choices between them as in real life.

4.4 Stated and revealed preference data

There are two types of data that can be used with the discrete choice analysis: stated preference data and revealed preference data.

The differences between the two types of data are shown in the following table (Table 4.1):

Element	Revealed Preference Data	Stated Preference Data
Preference	• Choice behaviour in actual markets • Complies with actual behaviour • Personal and environmental constraints are accounted for	• Preference statements for hypothetical scenarios • Many complies with actual behaviour • Market and personal constraints may not be considered
Alternatives	• Actual alternatives • Responses to possible new alternatives are unobservable	• Generated alternatives • Can include preference for new (not existing) alternatives
Attributes	• May include measurements errors • Correlated attributes • Ranges are limited	• No measurement errors • Multicollinearity can be avoided by experimental design • Ranges can be extended
Choice Set	• Ambiguous in many cases	• Pre-specified
Number of Responses	• Difficult to obtain multiple responses from an individual	• Repetitive questioning is easily implemented
Response Form	• Only choice is available	• Various response format are available

Table 4.1 *Differences between stated and revealed preference data (Source: The airport choice for scheduled freighter operations in Europe)*

4.5 Operate with stated preference data

The main difference between working with declared and revealed preference data is that, when dealing with declared preference data, it is an experiment instead of real observations.

So, in our study, it was decided to work with the declared preferences data.

In contrast to the data of the revealed preferences, the data of the declared preferences are not obtained from real life situations but through experimental projects with hypothetical situations, which are often managed by questionnaire.

Therefore, the analysis of the declared preferences data overcomes some of the problems associated with the analysis of preference data revealed as errors in the measurement of attributes, multicollinearity[7], ranges of restricted attribute levels and restriction of alternatives to existing alternatives.

On the other hand, with declared preference experiments, alternatives and attributes must be defined in advance. Therefore, the correct definition of these is fundamental for the quality of the results of the model.

The main advantage of the approach based on the declared preferences is that hypothetical and non-existent alternatives can be included in the experiment. Therefore, new methods and innovations can be included in the alternatives and the model results can be used for forecasting and calculating future market shares. Furthermore, the personal and environmental limitations that could exist in real-life situations from which the revealed preferences data are collected can be expanded.

However, the main reason why in the end it was decided to work with the declared preference data is that respondents may be asked to express their preference in several chosen situations.

The process of setting up a discrete analysis experiment using declared preference data is shown in the diagram of the previous figure (Figure 4.1).

First, the problem must be clearly defined. This includes considerations about what question the researcher is trying to answer and which method is the most appropriate to answer that question.

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[7] Multicollinearity arises when there is a high correlation between two or more explanatory variables. In a regression model Y = X1, X2, X3 if X2 is a linear transformation of X1 and therefore a relation of the type X2 = a + bX1 exists, the two variables are perfectly correlated.

After defining the research problem, it is necessary to select a methodology and a model that respond specifically to research needs.
Different types of models can be distinguished, such as the multinomial logit model, the nested multinomial logit model and the mixed multinomial logit model.
The model must also be specified including the alternatives, attributes and attribute levels.
One of the main parts in creating a declared preference study is design generation.
Good design can maximize experiment information. Once the drawing has been generated, a questionnaire is created.
If required, it may also include other questions to obtain information that is needed as input for the declared preference analysis, such as socioeconomic variables or information needed to answer research questions. In the experiment on the declared preference regarding the port choice of container shipping operators, for example, further questions were asked, as will be seen later.
Finally, the data for the analysis of the declared preferences must be collected to estimate and subsequently interpret the indicated preference model.
In this way, it will be possible to obtain an answer to the initial question and therefore the last phase will be precisely to verify whether this response can be satisfactory or not, and in the latter case go to find the countermeasures that can be adopted.

4.6 Behind the Discrete Choice Analysis

Before to go in depth with the model specification some clarifications must be done about what is behind the methodology used.
Since it incorporates various economic theories, the theoretical foundation of discrete choice analysis is rather complex. The analysis of the discrete choice is first based on the probabilistic theory, since it is not possible to perfectly predict the choices due to unobservable parameters.
Therefore, instead of identifying an option as the chosen option, each alternative is given a probability to choose. Moreover, the analysis of discrete choice is in line with the economic theory of Lancaster K. J.[8] (1966) which states that the utility of a good or service derives from

[8] Kelvin John Lancaster (10 December 1924 - 23 July 1999) was an Australian mathematical economist and John Bates Clark professor of economics at Columbia University.

its different "hedonistic"[9] characteristics and not from the good itself, as the theories of consumer demand.

Another theory that can be considered as the foundation of discrete choice analysis is the "Law of comparative judgment"[10] by Thurnstone L.L.[11] (1927) in which he sought to explain imperfect discrimination.

In 1960 the idea of Thurnstone L.L in treating preferences as stochastic or random was generalized by Marschak J.[12], going to build the "Random Utility Model (RUM)"[13].

In 1959 the scientist Luce D.[14] also introduced the "Axiom of independence from irrelevant alternatives"[15], to facilitate the experimental measurement of the probability of choice.

McFadden[16] (1974) combined all these ideas and highlighted a new model called "MNL model" (Multinomial Logit)[17].

[9] Utility is not expressed in terms of product quantities, but in terms of quantity of product characteristics. To maximize its utility, the consumer does not evaluate the goods, but their individual characteristics, choosing the product that presents the combination of attributes that gives it the greatest satisfaction.

[10] "The smaller the difference between two stimuli, the smaller is the number of people able to perceive it "; psychometric theory aimed at the study of the measure of comparative judgment; what are the psychometric factors that influence a consumer's judgment.

[11] Louis Leon Thurstone (Chicago, May 29, 1887 - Chapel Hill, September 29, 1955) was an American engineer and psychologist, pioneer in the field of psychometrics and psychophysics. He became famous in the world because he first measured attitudes, starting a whole line of psychological studies.

[12] Jacob Marschak (23 July 1898 – 27 July 1977) was a Ukrainian-American economist, known as "the Father of Econometrics".

[13] Model referring to the random utility theory (random utility indicators).

[14] Robert Duncan Luce (May 16, 1925 - August 11, 2012) [1] was an American mathematician and social scientist, and one of the most preeminent figures in the field of mathematical psychology. At the end of his life, he held the position of Distinguished Research Professor of Cognitive Science at the University of California, Irvine.

[15] Basic axiom among the hypotheses of the impossibility theorem of Arrow, or simply theorem of Arrow. Arrow's theorem is a theorem based on an impossibility theory formulated by the economist Kenneth Arrow (Kenneth Joseph Arrow (also called Ken) (New York, August 23, 1921 - Palo Alto, February 21, 2017) was a US economist, winner of the Nobel Prize for economics in 1972, together with John Hicks, for pioneering contributions to the theory of general economic equilibrium and the theory of well-being) in his Social Choices and Individual Values (1951). This theory states that, given a priori "universality", "non-imposition", "non-dictatoriality", "monotonicity" and "independence from irrelevant alternatives", it is not possible to determine a voting system that preserves social choices.

[16] Daniel Little McFadden (born July 29, 1937) is an American econometrician who shared the 2000 Nobel Memorial Prize in Economic Sciences with James Heckman. McFadden's share of the prize was "for his development of theory and methods for analyzing discrete choice". He is the Presidential Professor of Health Economics at the University of Southern California and Professor of the Graduate School at University of California, Berkeley.

[17] In statistics, multinomial logistic regression (multinomial logit model) is a classification method that generalizes logistic regression to multiclass problems, i.e. with more than two possible discrete outcomes. That is, it is a model that is used to predict the probabilities of the different possible outcomes of a categorically distributed dependent variable, given a set of independent variables.

5 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, they state that "*the probability that individuals choose a particular alternative is a function of their socioeconomic characteristics and the relative attractiveness (utility) of the alternative*".

Any individual or any respondent is considered a *homo economicus*, and therefore:

- 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.

The points of view that can be observed in a model of this type are two: that of the individual and that of the modeller.

The first, as we have seen, has a perfect knowledge of the landscape that is judging and always chooses the alternative with the maximum utility (perfectly behavioural theory), keeping in mind that the preferences of individuals are always consistent and transitive (they are not always observed rational behaviour).

The point of view of the modeller, instead, is the 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 various factors:

- a systematic component (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.)

5.1 Multinomial Logit Model (MNL)

One of the simplest and most common discrete choice models, already mentioned in the previous pages, is the multinomial logit (MNL) model that was first introduced by McFadden (1974).

In this model the relative utility of an alternative in a choice situation can be written as follows:

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

where is it

- 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 [18]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* is (McFadden, 1974):

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

The three most important shortcomings of the MNL model are that first, it does not account for taste heterogeneity between respondents. Second, it does also not account for the fact that the respondents usually answer multiple choice tasks and therefore correlations might be introduced.

Third, it is assumed that the unobserved components of the utility are independent and identically distributed.

To understand this third assumption, one has to understand that as the unobserved components of the utility function have to be independent and identically distributed. Furthermore, the ratio

[18] In probability theory, the Gumbel distribution (or EV1-Extreme Value type 1) is a continuous two-parameter probability distribution. It is used to describe the extreme values of a continuous stochastic series.

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.

5.2 Notes concerning the estimation of the discrete choice models

In order to enable the reader to understand the model calculations in the following chapter and to better follow the interpretation of the results, some additional issues should be discussed. First, the maximum likelihood approach that is used to estimate the discrete choice models will be presented.

Subsequently, some hypothesis tests such as the maximum likelihood ratio test.

5.2.1 The maximum likelihood estimation

Models such as the MNL model are based on the estimation of the maximum likelihood.

The purpose of the approach is to find partial values that most likely determine the choices observed. This means that we look for the value of the parameters in the utility function that will most likely determine the choices made by respondents.

For a binary multinomial logic model, or a model resulting from the fact that the responder makes a choice between two alternatives at a time, the probability of a sample consisting of N observations can be defined as:

$$L(\beta_1, \dots, \beta_k) = \prod_{n=1}^{N} \sum_{s=1}^{S} P_{ns} (1)^{y_{1ns}} P_{ns}(2)^{y_{2ns}}$$

where:

- L is the probability that depends on the parameters $\beta_1, \dots, \beta_k$;
- $P_{ns}(1)$ and $P_{ns}(2)$ are the probabilities with which the alternative 1 or 2 is chosen respectively;
- y_{1n} is 1 if the individual n has chosen alternative 1, and 0 otherwise;
- y_{1n} is 1 if the individual n has chosen alternative 2, and 0 otherwise.

The product of all probabilities is maximized with respect to $\beta_1, \dots, \beta_k$, to obtain the maximum likelihood.

The likelihood function will be between 0 and 1 as it is a product of probabilities (which is between 0 and 1).

However, mathematically it is easier to maximize the logarithm of the likelihood function, which is equivalent:

$$l(\beta_1, \dots, \beta_k) = log\big(L(\beta_1, \dots, \beta_k)\big)$$

or

$$l(\beta_1, \dots, \beta_k) = \sum\nolimits_{n=1}^{N} \sum\nolimits_{s=1}^{S} (y_{1ns}\, log\, P_{ns}(1) + y_{2ns}\, log\, P_{ns}(2))$$

The problem is, therefore, to find the values for the parts that maximize the probability of log-likelihood.

Since the probability will be between 0 and 1, the log-likelihood function will be negative. The maximum of the log-likelihood function is, therefore, the value closest to zero and the closer the log probability is to zero, the better the model explaining the data.

To be able to find the maximum likelihood estimates, several optimization algorithms are available.

Furthermore, an important quality of the likelihood function that is very useful for evaluating the goodness of adaptation, the so-called deviance, is that $-2 \log L$ or $-2\ l$ is approximately chi-squared distributed.

5.2.2 The likelihood ratio test

The likelihood ratio test is performed to compare the fit of two different models that are a variation of each other with estimating the models and comparing their fit to each other. This is done by comparing the log-likelihoods of two models and to check whether those differ significantly from each other.

Let θ be a vector of parameter estimates, L_U the likelihood of the unrestricted model, the one with more parameters, and L_R the likelihood of the restricted model, the one with fewer parameters.

The likelihood ratio can, therefore, be defined as:

$$\frac{L_R}{L_U}$$

Furthermore, the likelihood ratio test D is actually a comparison between the deviance of the restricted and unlimited model and is defined as follows:

$$D = -2\, log\left[\frac{L_R(\theta)}{L_U(\theta)}\right] = -2\,[l_R(\theta) - l_U(\theta)]$$

under the null hypothesis, that the restricted model is equal to the unrestricted model, and which is chi-squared distributed with the degrees of freedom equal to the number of restrictions imposed.

The disadvantage of the likelihood ratio test is that it can only be applied when one model is a more restricted version of the other.

The likelihood ratio test will mainly be used for testing two different things: first to test whether the model has some statistically significant explanatory value overall and second to test whether individual or groups of parameters are statistically significant (as we will see in the chapter dedicated to the analysis of the results).

To see whether the full model is statistically significant, the estimated model is compared to a trivial model that has no explanatory value and in which all betas were assumed to be zero.

The specific log-likelihood ratio test would then be defined as:

$$D = -2\,[l(\theta) - l_0(\theta)]$$

with $l(\theta)$ being the log-likelihood of the estimated model and $l_0(\theta)$ the log-likelihood of the trivial model.

As we will see later in the chapter dedicated to the analysis of the results of the model, the value of this test of the likelihood ratio studied, going to make some considerations, which in the case of this research will be very important. When the p-value of D is small, the conclusion is that the difference in the log-likelihood of the models is significant and the estimated model fits the data much better than the trivial model.

This means that the estimated model has a statistically significant explanatory value.

The second use of the likelihood ratio test in this research concerns the test if certain parameters or groups of parameters have an explanatory value.

To this end, the adaptation of, for example, a simple MNL model that includes all the parameters, is compared with the adaptation of a limited model, through a test of the likelihood ratio. If the difference in adaptation is statistically significant, this means that the less restricted model (which is the simple MNL model that includes all the parameters) adapts to the data in a significantly better way than the limited model, the test of the likelihood ratio will be significant. If the probability ratio is not significant, the parameters can be excluded without the loss of significant explanatory value.

6 DEFINITION OF ALTERNATIVES AND ATTRIBUTES

6.1 Definition of alternatives

First of all, a choice 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. An option is to work with unlabelled alternatives in which the alternatives are not defined by their real name but only by their attributes and attribute levels.

In this study, it was decided to follow this approach.

In this case, however, this tactic was used not to limit the alternatives but rather to generalize them. Furthermore, when working with labelled alternatives, the attribute levels do not vary as much as in an untagged experiment if the choices are kept as realistic as possible.

Precisely for this reason, it was decided to work with the unlabelled alternatives (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.

In this way, it was possible to play with various combinations of variations of attributes and this has done nothing but make the study carried out more casual and probabilistic.

As we will see in this chapter the search for the attributes and the levels that define them has been fundamental to be able to define then the alternatives that it has been decided to reduce, as specified before, to only two elements.

So, in this research, we will address a discrete analysis study based on the use of two distinct alternatives, characterized by different attribute levels. Later, as will be seen, we will talk about alternative A (Port A) and alternative B (Port B).

6.2 Definition of attributes

A second step in specifying the model is the identification of the factors/attributes of the choice of the airport and their levels to be used in the discrete choice analysis.

The research of the attributes (EPI "Environmental Performance Indicator" or PSI "Port Sustainability Indicators") used in the study carried out here, has been conducted with a careful and detailed revision of articles and documents (reported in the bibliography), which deal in depth and never in the same way with the description of the factors that can influence the concept of port greening.

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*".

The indicators are developed and used mainly to highlight the performance of a biological, physical, chemical, environmental, economic or social system and in the case of the environment, the EPIs relate to the impact of an organization on living and non-living natural systems, including ecosystems, air, water, soil and sediments.

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

- 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;
- can be used to assess the effectiveness of implemented policies, measuring progress towards environmental objectives and to provide a reference basis for future objectives. - have a key role in providing early warning information, which can serve as a signal in the event that the situation worsens, indicating the risk before serious damage occurs;
- can be used as a powerful tool to raise public awareness of environmental issues.

Within the port sector, potential users of environmental indicators include:

- workers of the Port Authority;
- companies and industries that invest in the port (such as terminal operators or maritime agencies);
- political decision makers;
- civil society organizations.

Other indicator users include:

- auditors;

- banks;
- insurance companies.

The development and selection of environmental indicators 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 indicators should be accompanied by a rigorous validation process.

Although several methods for selecting indicators have been suggested, there are two main approaches to selecting indicators: top-down and bottom-up.

The top-down approach is based on the identification of indicators from the literature review (e.g. publications, reports and standards) and on the restriction to a final set of agreed indicators. The bottom-up approach consists of compiling the final set of indicators 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.

6.3 Port Sustainability Indicators according to “ESPO ENVIRONMENTAL REPORT 2018”

The most important document consulted in this phase of the research, which provided more important than the others the most important guidelines is, without any doubt, "ESPO ENVIRONMENTAL REPORT 2018". This document, issued each year by ESPO, contains the key points of the aspects which will then be discussed below.

To go into the details of what was said, the first operation that was carried out was that of a real separation of the attributes in two fundamental categories:

- environmental management indicators;
- environmental monitoring indicators.

The environmental management indicators provide information about the management elements that influence the environmental performance of a port.

The table (Table 6.1) below, shows a list of these indicators according to the research conducted by ESPO, and it is shown the change (in percentage) of their importance from 2013 to 2018 (last updating).

Indicator	Change 2013-2018
Existence of Certified Environmental Management System EMS (ISO, EMAS, PERS)	+19%
Existence of an Environmental Policy	+6%
Existence of an inventory of relevant environmental legislation	+7%
Existence of an inventory of Significant Environmental Aspects (SEA)	+9%
Definition of objectives and targets for environmental improvement	+9%
Existence of an environmental training programme for port employees	-8%
Existence of an environmental monitoring programme	+10%
Environmental responsibilities of key personnel are documented	+15%
Environmental Policy refers to ESPO's guideline documents	-2%
Publicly available environmental report	+6%

Table 6.1 *Environmental Management Indicators according to ESPO (Source: ESPO Environmental Report 2018)*

As can be seen, the existence of an EMS is the indicator that has the highest percentage change (+19%). The second highest change percentage is the existence of an environmental monitoring programme (+10%) to improve ports' environmental performance. Then, all the others, with particular attention to the indicators which have registered a decreasing change percentage. It means that in that field there are significative lacks and gaps.

It has to be said that the introduction of port's environmental policy, that registered a change percentage of +6% from 2013 might be a first significant step towards a certified Environmental Management System (EMS). This means that there are much more awareness and much more judgment on the fact that there should be a formal and well-detailed regulation on the management of the port at the environmental level.

The environmental monitoring indicators are focused on the environmental monitoring programmes of ports. These indicators provide information about the monitoring elements that influence the environmental performance of a port.

The table (Table 6.2) below, shows a list of these indicators according to the research conducted by ESPO, and it is shown the change (in percentage) of their importance from 2013 to 2018 (last updating).

Indicator	Change 2013-2018
Waste	+17%
Energy Consumption	+15%
Water Quality	+20%
Water Consumption	+14%
Noise	+16%
Air Quality	+15%
Sediment Quality	+2%
Carbon Footprint	-1%
Marine Ecosystem	+5%
Soil Quality	-4%
Terrestrial habitats	0%

Table 6.2 *Environmental Monitoring Indicators according to ESPO (Source: ESPO Environmental Report 2018)*

As can be seen, there has been an increase of 17% of ports monitoring waste in the last 5 years. This is followed by climate-related energy consumption that increased +15% since 2013 and water quality and consumption (+20% and +14% respectively) followed by noise and air quality which went up by 16% and 15% respectively.

The climate-related carbon footprint has been almost stable in the last 5 years, just with a change of 1% in decreasing; the same condition also for terrestrial habitats (that has had no change). Soil quality is the issues with the lowest percentage of change; it means that is not so important as a parameter to pay attention to according to the ESPO researches.

Always according to ESPO, must be considered a very important element that is influenced by environmental monitoring indicators. It can be seen as the result of the environmental parameters' change and it is the "climate change".

Figure 6.1 *Top Ten Environmental Priorities (Source: ESPO Environmental Report 2018)*

Ports must take into consideration climate change when they develop new infrastructure projects and new change in their environmental monitoring and management systems.

From the study of these indicators, ESPO has managed over the past 5 years to draw up a classification called the "ranking of the ten environmental priorities".

It can be seen as real information support.

This is a significant summary because it shows the priority status ascribed by port professionals to current issues that are assessed as being important and noteworthy in terms of the port's environmental management programme.

These data are important because it identifies the high priority environmental issues on which ports are working and sets the framework for guidance and initiatives to be taken.
The "Top Ten Environmental Priorities" can be seen in the figure (Figure 6.1), with all the changes since 2013.

6.4 Port Sustainability Indicators according to other researches

Although the description of these indicators provided by ESPO is very complete and detailed, it is not enough to satisfy the needs of our search for attributes. This is because, unfortunately, ESPO, has only conducted work on European ports. So obviously the infinity of ports present in the rest of the world would be missing.
So, the search for attributes has been expanded by going to review documents and articles that touch the theme of environmental priorities in the ports of the world.
Over time an extensive list of EPIs has been compiled thanks to the various research carried out.
In order to provide an exhaustive database of possibilities, this collection was based on an extensive review of the literature and on the identification of the current best industrial and sectorial practices. The indicators were analyzed individually and filtered based on specific criteria. In order to guarantee a reliable and satisfactory selection process, a wide consultation was also conducted with port stakeholders, with the participation of workshops, focus groups and conferences.
At the end of this phase, a personal list of attributes was drawn up, and their definition in levels, which will be subsequently shown.
Proceeding with an order, it would be appropriate to go on to describe some more details of the bibliographic research performed to select these attributes.
According to what is also specified in the previous chapters, first of all, an indicator must have the following features (here all characteristic has a definition) (Table 6.3):

Characteristics	Definitions
Representativeness	The indicators should represent environmental behaviour as accurately as possible
Conciseness	The indicator should allow for the simplification of the number of variables, which characterizes a phenomenon of considering the information with the least possible loss of information
Purpose	The indicator should allow an activity to be evaluated in such a way that goals are accomplished
Usefulness	The indicator should be a useful tool for the activity
Relevance	Within the environmental awareness framework
Adaptability	Being adapted or easily adapted to other indicators, models and prediction systems (EEA, ODCE, etc.)
Comparability	Over time (the development of a phenomenon), and within regional national and international frameworks
Sensitivity	The indicator should be sensitive to environmental changes with fast, adaptable and appropriate responses to them. Thus, they should have variable values according to the changes in the phenomenon
Clarity	The system should be coherent and focus on essential data. The indicators should be

	concise, accurate, simple and easy to interpret
Reliability and objectivity	In obtaining and developing the data
Easy to obtain	From the phenomenon being evaluated
Continuity	The collecting data criteria should be constant over time in order to compare results
Regularity	The indicators should be determinate at appropriately short intervals for the purpose of having the opportunity to actively pursue and influence the desired data
Scientific verification	The indicator should be preferably quantitative. If this were not possible, it should be hierarchically categorized
Well defined limits	The indicator should provide information about its own limitations
Cost-effectiveness	The indicator should be administratively efficient in terms of the costs involved in obtaining the data and use of the information

Table 6.3 *General characteristics of port sustainability indicators (Source: Development of a systems of indicators for sustainable port management)*

Until now, a series of researches have addressed the issue of environmental indicators for a green port strategy.

A multitude of statistical and analytical approaches (FAHP: Fuzzy Analytic Hierarchy Process, TEIP: Environmental Indicators Tool in Ports, can be mentioned) were used to conduct a selection and classification of these parameters and very often it has been noticed that almost all the carried out studies have reported a wide range of parameters in common.

By way of example and illustrative, some results of previous research are reported below in which some of the many environmental parameters influencing port ecology have been highlighted.

Starting from these, a table of selected indicators related to this research has been built.

The first example that is reported is from a very particular analysis made by Puig M., Wooldridge C. and Darbra R.M[19]. The figure below (Figure 6.2) reports the results of their analysis. This analysis has been very detailed because they divided the indicators into three categories according to the ISO 14031. It states that there are three categories of environmental performance indicators (EPI):

- management performance indicators (MPIs) that "provide information on management efforts that influence the port's environmental performance";
- operational performance indicators (OPIs) that "provide information on the environmental performance of port operations";
- environmental condition indicators (ECIs) that "provide information on environmental conditions".

Management Performance Indicators (128)	Operational Performance Indicators (80)	Environmental Condition Indicators (96)
Environmental Management System (5)	Resources consumption (14)	Air quality (12)
Environmental policy (11)	Carbon Footprint (10)	Water quality (26)
Objectives and targets (8)	Noise (13)	Soil quality (10)
Environmental monitoring programme (6)	Waste Management (28)	Sediments quality (20)
Significant Environmental Aspects (3)	Port development (15)	Ecosystems and habitats (20)
Management organisation and personnel (6)		Odour (8)
Environmental training and awareness (15)		
Environmental communication (15)		
Emergency planning and response (23)		
Environmental audit (5)		
Environmental legislation (8)		
Environmental complaints (8)		
Environmental budget (11)		
Other management indicators (4)		

Figure 6.2 *Indicators according to Darbra analysis (Source: Identification and selection of Environmental Performance Indicators for sustainable port development)*

[19] Authors of "Identification and selection of Environmental Performance Indicators (EPI) for sustainable port development" published in 2014 (see the reference at the end).

As is possible to see from the figure (Figure 6.2), the management performance indicators (MPIs) are divided into 14 categories, each of which then has further sub-categories (the number in brackets alongside each one) for a total of 128 indicators, all relating to the efforts made by the Port Authority for the implementation of effective environmental management within the organization.

Operational performance indicators (OPIs) comprise a total of 80 indicators, divided into 5 categories with the relative sub-categories (the number in brackets alongside each). These indicators focus on aspects associated with port authority operations, including activities, products and services. They can be divided into input indicators, such as resource consumption; and output indicators, such as waste production, carbon footprint or noise.

Port development indicators are also included in the operational indicators and concern operations carried out at sea, on land or in both.

The last ones are the environmental condition indicators (ECIs) which provide information on the quality and the state of the environment.

They are divided into 6 categories with the relative sub-categories (number in brackets alongside each), for a total of 96 indicators.

These indicators analyze the quality of air, water, soil and sediments. It also includes the "ecosystems and habitats" indicators that show the state and specific trends of flora and fauna.

According to the research conducted by Özispa N. and Arabelen G.[20] the following collection of environmental indicators has been established (Figure 6.3):

[20] Authors of "Assessment of port sustainability indicators in the sustainability reporting process" published in April 2018 (see the references at the end).

Environmental Indicators	Emissions of GHGs
	Emissions of air pollutants
	Noise
	Renewable/alternative energy usage
	Recycling of ships
	Recycling of hazardous wastes
	Recycling of equipment
	Emissions of GHGs/area of warehouse
	Emissions of GHGs/average service time for ships
	Emissions of GHGs/number of import and export containers
	Emissions of GHGs/annual revenues
	Fuel consumption
	Electric consumption
	Water consumption
	Air quality
	Atmospheric contaminant emissions: CO, NOx, SOx, PM10 particles
	Greenhouse effect (Carbon footprint): CO2, CH4, N2O
	Water quality
	Waste creation
	Waste disposal
	Eco-efficiency
	Wasted resources
	Material recycling
	Noise pollution
	Inner port water quality
	High risk areas for soil pollution
	Creation of sludge from dredging
	Efficient electric energy consumption

Figure 6.3 *Environmental indicators from previous researches (Source: Assessment of port sustainability indicators in the sustainability reporting process)*

This research pointed also the attention on other factors influencing the concept of sustainability in ports; they are the social indicators (Figure 6.4).

Social Indicators	Annual accident rate in port area
	Annual fatalities in port area
	Annual number of injured in port area
	Employee training
	Social impacts of operations
	Stakeholder engagements
	Human rights
	Workplace conditions
	Security

Figure 6.4 *Social indicators from previous researches (Source: Assessment of port sustainability indicators in the sustainability reporting process)*

Although fairly dated, the most complete research regarding a system of environmental indicators to be considered for the sustainability of ports was conducted in 2005 by Peris-Mora E., in collaboration with Diez Orejas J.M., Subirats A., Ibáñez S. and Alvarez P.[21]

In the following figures (Figure 6.5, Figure 6.6, Figure 6.7) there is a list of their parameters (on the right) based on the environmental impacts they produce (on the left):

Air pollution	
Emission of particles from storage, loading and unloading of bulk solids Emission of combustible gasses OC, NO_x, SO_2 and HC from vehicular traffic on land Emission of particles from the handling and transformation of bulk solids Emission of VOCs in loading and unloading combustible materials in activities with oil products	1. Air quality (atmospheric contaminant emissions: CO, NO_x, SO, O, PM10)
Emission of VOCs in storage tanks from oil product activity Emission of combustible gasses CO, NO_x, SO_2 and HC from maritime traffic Emission of combustible gasses CO, NO_x, SO_2 and HC from loading and unloading machines (cranes, water spouts, ramps, etc.) for containerised merchandise Emission of other gasses which are harmful for human health and/or the environment (VOCs) in building and repairing vessels	2. Atmospheric contaminant emissions: VOCs and particles
Emission of particles from civil works Emission of particles from vehicular land traffic Emission of particles from handling general containerised merchandise Emission of particles from building and repairing vessels	3. Gas emissions with Greenhouse effect (CO_2, CH_4, N_2O)
Noise pollution	
Noise caused by land traffic Noise caused by container loading and unloading machinery Noise caused by civil works machinery Noise caused by vessel construction and repairing machinery	4. Noise pollution
Odour pollution	
Odours from handling and transforming perishable bulk solids Odours from MARPOL V waste treatment Odours from fish handling Odours from water purifiers	

Figure 6.5 *Air, noise, odour pollution impacts according to Peris-Mora (Source: Development of a system of indicators for sustainable port management)*

[21] Authors of "Development of a systems of indicators for sustainable port management" published in 2005 (see the references at the end).

From the analysis is possible to understand that the main indicators that summarize this part are:

- air quality (CO, NO_x, SO, O, PM_{10});
- atmospheric contaminant emissions (VOCs and particles);
- gas emissions with Greenhouse effect (CO_2, CH_4, N_2O);
- noise pollution.

Water pollution	
Spills or leaks from the transfer of oil products from vessel to lorry Spills or leaks from the transfer of bulk liquids from vessel to lorry	5. Inner port water quality
Accidental spills from small vessels in maritime traffic Change in normal dock water conditions in dredging operations	6. Amount and description of accidental spills in inner port waters
Rainwater in bulk storage areas Processed water—with organic waste from fish cleaning	7. Quality of spilled waste water
Soil pollution	
Spills or leaks of dangerous liquids (HC, paints, solvents, oils) from land traffic Spills or leaks of dangerous liquids (HC, paints, solvents, oils) from construction and vessel repair Spills or leaks of dangerous liquids (HC, paints, solvents, oils) in the MARPOL waste treatment Leached material from storage of waste from fishing activities Leached material from storage of stock	8. High risk areas for soil pollution
Waste creation	
Urban waste Uncontaminated sludge from dredging Scrap from building and repair of vessels Non-organic waste: tyres in general containerized merchandise Scrap from civil works General organic waste from the handling of bulk solids Non-organic waste: tyres in port services Excesses from bulk solids stock Dangerous waste Material impregnated with dangerous chemical substances and preparations Batteries and fluorescent tubes Toxic waste packaging from building and repairing vessels (lubricants, solvents paint, anti-fouling, etc.) Toxic waste packaging in marinas (lubricants, solvents, paint, anti-fouling, etc.) Chemical preparations and organic solvents used in bulk solid activity	9. Urban and dangerous waste creation

Figure 6.6 *Water, soil pollution and waste creation impacts according to Peris-Mora (Source: Development of a system of indicators for sustainable port management)*

From this second part the main indicators summarized are:

- inner port water quality;
- amount and description of accidental spills in inner port waters;
- quality of spilled waste water;
- high-risk areas for soil pollution;
- urban and dangerous waste creation.

Resource consumption	
Consumption of processed water in the manipulation and transformation of perishable bulk solids Water consumption in cleaning and maintaining green areas Water consumption in watering carbon heaps when handling bulk solids Water consumption in cleaning and maintaining crafts in marinas	11. Efficient water consumption
Fuel consumption in land traffic Fuel consumption in machinery used for the storage, loading and unloading of containerised merchandise Fuel consumption in machinery used for building and repairing vessels	12. Efficient fuel consumption
Electric energy consumption in the storage, loading and unloading of containerised bulk solids Electric energy consumption in the storage, loading and unloading of non-containerised bulk solids Electric energy consumption in the storage, loading and unloading of non-containerised merchandise Electric energy consumption the handling and pumping of oil-based derived products Electric energy consumption in the handling and pumping of bulk liquids	13. Efficient electric energy consumption
Other	
Alteration of water currents due to the existence of the port, accretion and erosion phenomena Alteration of sea floor due to civil works Alteration of sea floor due to dredging operations Alteration of sea floor at the mooring areas for boats	14. Alteration of sea floor
Occupation of soil due to civil works Impact on landscape and installations that are abandoned or out of use	15. Soil occupation efficiency
	16. Social image of the port 17. Number of incidents with environmental repercussions

Figure 6.7 *Resource consumption and other impacts according to Peris-Mora (Source: Development of a system of indicators for sustainable port management)*

From this third part the main indicators summarized are:

- efficient water consumption;
- efficient electric energy consumption;
- alteration of sea floor;
- soil occupation efficiency;
- social image of the port;
- number of incidents with environmental repercussions.

6.5 Our Port Sustainability Indicators as attributes

Starting from the previous concepts just seen, for us it was possible, in a very clear and meaningful way, to create a grouping of a series of port greening indicators, which we will call more simply port sustainability indicators.

Initially, a number of indicators exceeding fifteen were found. Since the study addressed here it is not appropriate to have an excessive number of variables, it was considered significant to reduce these indicators to an attainable number.

In accordance with our opinion and our research, 7 indicators of port sustainability and environmental performance have been established.

Each of them has been divided into further degrees of specification.

The first degree corresponds to the actual indicator, the second degree corresponds to the splitting of the indicator into various elements that help to define it and the third degree 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:

- cost and charges (always present in an analysis like this);
- air pollution
- noise pollution
- water pollution
- resource consumption
- port capacity and productivity
- port environmental improvement and development.

Below, in the table (Table 6.4) the indicators used in this research are shown:

1st GRADE	2nd GRADE	3rd GRADE
COSTS AND CHARGES	**Cost of supplied services for goods**	Storage costs Land cost (inland transhipment freight rates and other land transport costs associated with the port) Major costs for harmful goods Terminal charges
	Port costs and fees	Port charges (mooring, pilot cost, port dues, towage, …) Dwell time Rent of containership berth Other dues
	Cost of supplied fuel	Refuel ship tankers during the stopping phase in the port
	Cost of supplied energy	Energy supplied during the stopping phase in the port for any kind of operation and any kind of needed; less is the stopping phase less will be the energy required from the quay loading energy equipment and less will be the price to pay by the shipping company
	General port charges	Any kind of port charge due to any kind of operation and needed requested from the shipping company in the port stopping phase
	Atmospheric contaminant emissions: CO, NOx, SO, O, PM10	Emission of particles from handling and transformation of bulk solids Emission of VOCs in loading and unloading combustible materials in activities with oil products Emission of VOCs in storage tanks from oil product activity Emission of combustible gasses from maritime traffic
	Atmospheric contaminant emissions: VOCs and particles	

AIR POLLUTION	**Gas emissions with Greenhouse effects: CO_2, N_2O, CH_4**	Emission of combustible gasses from loading and unloading machines (cranes, water spouts, ramps, …) for containerized goods Emission of other gasses which are harmful to human health and the environment in building and repairing vessels Emission of particles from various works (civil works, vehicular works, handling containerized goods works, repairing vessels works) Emission from combustible gasses CO, NO_X, SO_2, and HC from vehicular traffic on land Ship activities in stopping phase (lighting, heating, refrigeration, ventilation, tanker loading and unloading) Emissions from engines Loading and unloading of petroleum products produce volatile organic compound emissions Dry docks operations Passenger car traffic (combustion emission and evaporative volatile organic compound emissions) Heavy vehicle (trucks) traffic (combustion emissions) Railway traffic (combustion emissions) Demolition or main modification of ships Emissions of GHGs / (area of warehouse, average service time for ships, number of import-export containers, annual revenues) Dust Speed of vessels (lower is the speed of vessels and less will be the dangerous emissions)
	Odour pollution	Odour from handling and transforming perishable bulk solids

		Odour from any kind of waste treatment Odour from water purifiers
	Carbon footprint	Greenhouse effects on air: CO_2, CH_4, N_2O, HFC, PCF, SF_6
NOISE POLLUTION **(waterborne, airborne, structure borne)**	**Noise caused by land traffic and maritime traffic**	Propulsion machinery Auxiliary engines (steam turbines, diesel engines) Propellers Heating ventilation fun Air conditioning systems engine sound Noises from vehicle (car, trains, trucks, lorries) Goods movement (crane, pumps, straddle carries, semitrailer, …)
	Noise caused by container loading and unloading machinery	Operation machineries Traffic generated in the storage area with handling means Vibrations
	Noise caused by civil works machinery	Vibrations Industrial activities in port area Several works in port (constructions, modernizations, …)
	Underwater noise	Any kind of noise caused by electronic devices, mechanical systems, and other ship equipment under the level of water.
		Change in normal dock water conditions in dredging operations

WATER POLLUTION	**Port water quality**	Rainwater in bulk storage areas Run-off water and cleaning water Marine Ecosystems Pollution from slop (residual of chemical products contained in the tanks and of the product used in the washing operations) Leaching of antifouling paints used to coat the bottoms of ships to prevent sea life attaching to the hull Storm water runoff from port parking lots Water thermal pollution Water stagnation due to weak water turnover Dredging and excavation of port areas with resuspending of materials and pollutants Wastewater
	Accidental spills in port waters	Accidental spills and leaks in the dock during operations Oil of bilge and engine fuel leakage from ships and gasoline and diesel oil leakage from pleasure crafts Operations on terminals and fuel deposits (accidental discharge of oil in the sea, loss from deposit tankers and pipeline) Dry docks operations (accidental discharge of oil and other chemicals in the sea) Ship demolitions (accidental discharge of oil and other chemicals in the sea)
	Quality of spilled waste water	Dredging operations in the port by any kind of vessel

RESOURCE CONSUMPTION	**Electric energy consumption**	Electric energy consumption in the storage, loading and unloading of containerized and non-containerised bulk solids Electric energy consumption in the storage, loading and unloading of non-containerised goods Electric energy consumption in the handling and pumping of oil-based derived products Electric energy consumption in the handling and pumping of bulk liquids
	Fuel consumption	Fuel consumption in land traffic Fuel consumption in machinery used for the storage, loading, and unloading of containerized goods Fuel consumption in machinery used for building and repairing vessels
	Water consumption	Water consumption in cleaning and maintaining port areas (green areas, terminal cleanliness, storage areas cleaning, …)
	Waste creation and disposal	Everything related to the waste category illustrated separately
	Provision of LNG bunkering facilities	Everything related to the treatment of LNG in suitable plant General treatment (condensate removal, CO_2 removal, dehydration, mercury and H_2S removal) Refrigeration Liquefaction Storage and then loading
	Supply at port berth (OPS)	Electrification of operations (one step towards sustainable energy: using equipment to produce polluted energy reducing also the emissions and other kind of dangerous wastes)

PORT CAPACITY AND PRODUCTIVITY		
	Availability of feeder facilities	Any kind of operation in which are involved feeding equipment
	Provision of services	Any kind of service and needed to support the ship stopping phase as suitable as possible
	Congestion (waiting time and delay)	Time for loading and unloading in order to the availability of the equipment Port berthing time
	Capacity to store and handle hazardous cargo	Safety in handling container and various goods (also dangerous goods)
	Capacity to manage a big volume of traffic	Container yard efficiency Number of TEU/hour handled Number of docks and port Port loading /unloading efficiency
	Restrictions on handling and restrictions in ports	Restrictions on hour for loading and unloading Restrictions on hour for entering and mooring in the port Restriction on forbidden operations on handling
	Experience, readiness and availability of port	Responsibility of key personnel Existence of training programme for port workers and personnel Customs efficiency

		Relationship between management and workers
	Quality of supplied services (quality of fuel, of quickness in operations, availability of machinery as cranes and means for container handling, availability of berths, …)	Berth availability Operation strategy Port operation efficiency Workplace conditions Security of operations Safety equipment Operators' expertise and ability Others
	Existence of a certified environmental management system (EMS) under ISO, EMAS, PERS standardization	All these elements coming from regulations. Every port can have its own regulation issued from Port Authority or from the operating companies in onshore plant and berths. It is needed for any port to dispose of: EMS, EMP, SEA to be kept into account in a specific situation (risk, emergency, threat, uncertainty, danger, hazard, disaster, eventuality, unexpected, disaster, alert and warning, etc…)
	Existence of environmental monitoring programme (EMP)	
	Existence of an environmental policy and legislation	
	Presence of an environmental inventory of significant aspects (SEA)	

PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT	**Targets for environmental improvement and port development**	Development land side Development sea side
	Geographical advantages	Proximity to the markets (demands) and cargo availability Good international and intermodal connectivity Port location
	Relation with communities and human settlements	Relation with communities Impact of noises, air pollution on local communities Impact of operations and decision on people Reduction of externalities on society Influence on terrestrial habits

Table 6.4 *Port Environmental Indicators selected for this study (Source: own composition)*

Point the attention on the "resource consumption" indicator it is possible to find, in the second-grade specification, an element called "waste creation and disposal". To be precise, would be right to explain that the relationship between resource consumption and waste creation comes from the consideration, in our research, about waste creation as a result of energy consumption.

The waste creation has been considered as a consequence of energy consumption, and this is why it has been aggregated to that indicator.

In the following table (Table 6.5) is reported and explained the sub-indicator of waste creation.

In the second grade specification of this indicator, we considered appropriate to insert the voice of "soil pollution". We reputed it not so essential to be added in the ranking of first seven.

1st GRADE	2nd GRADE	3rd GRADE
WASTE CREATION AND DISPOSAL	Urban waste	Scrap from vessels Uncontaminated sludge from dredging Excesses from bulk solid stock Nonorganic waste General organic waste
	Dangerous waste	Material impregned with dangerous chemical substances Toxic waste packaging Chemical preparations and organic solvents used in bulk solid activity Contaminated sludge from dredging Oil terminals and fuel deposits (oily and toxic sludges) Dry docks operations (oily and toxic sludges) Ship demolition connected with the nearly complete absence of facilities for handling waste residues from the demolition process Recycling of hazardous wastes
	Soil pollution	Sediment quality and soil quality (accidental spills or leaks of dangerous liquids from vessels, from the bulk handling devices, from demolition of ships, dust dispreads during handling, discharge of wastewater and chemicals matters and hydrocarbons)
	Raw materials consumption	Raw material recycling in a not suitable way

Table 6.5 *Waste creation indicator and its grades (Source: own composition)*

6.6 Description of chosen attributes

The attributes found are going to be explained in detail below.

As learned from ESPO, in our case, is possible to make a difference between:

- environmental monitoring parameters (air pollution, noise pollution, water pollution, resource consumption);
- environmental management parameters (cost and charges, port environmental improvement and development, port capacity and productivity).

Firstly, monitoring parameters will be faced.

Before to go in depth in the description of the environmental monitoring attributes chosen for the analysis would be suitable to report two diagrams (Figure 6.8 and Figure 6.9) from literature in which is possible to see and understand how the process of port pollution takes place through most of the operations involved and what are the targets for measuring the degree of greening of a port.

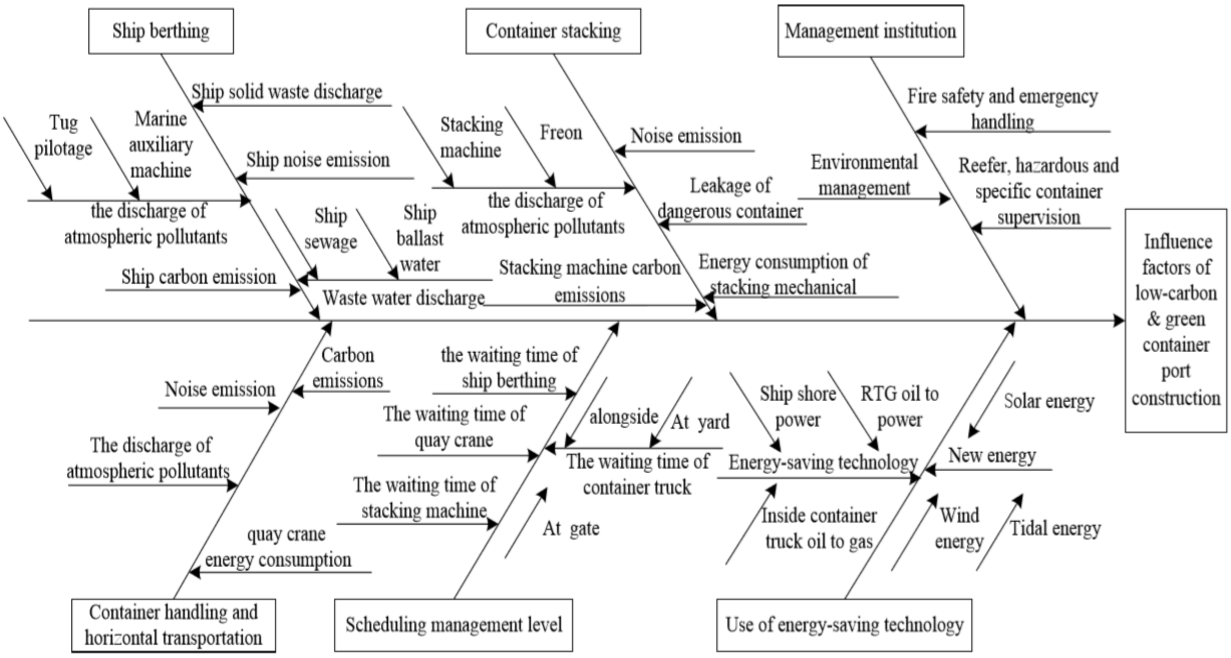


Figure 6.8 *Discharge operation process of container ships with influencing elements for the greening grade of the port (Source: Analysis on low-carbon and green container port building goal system)*

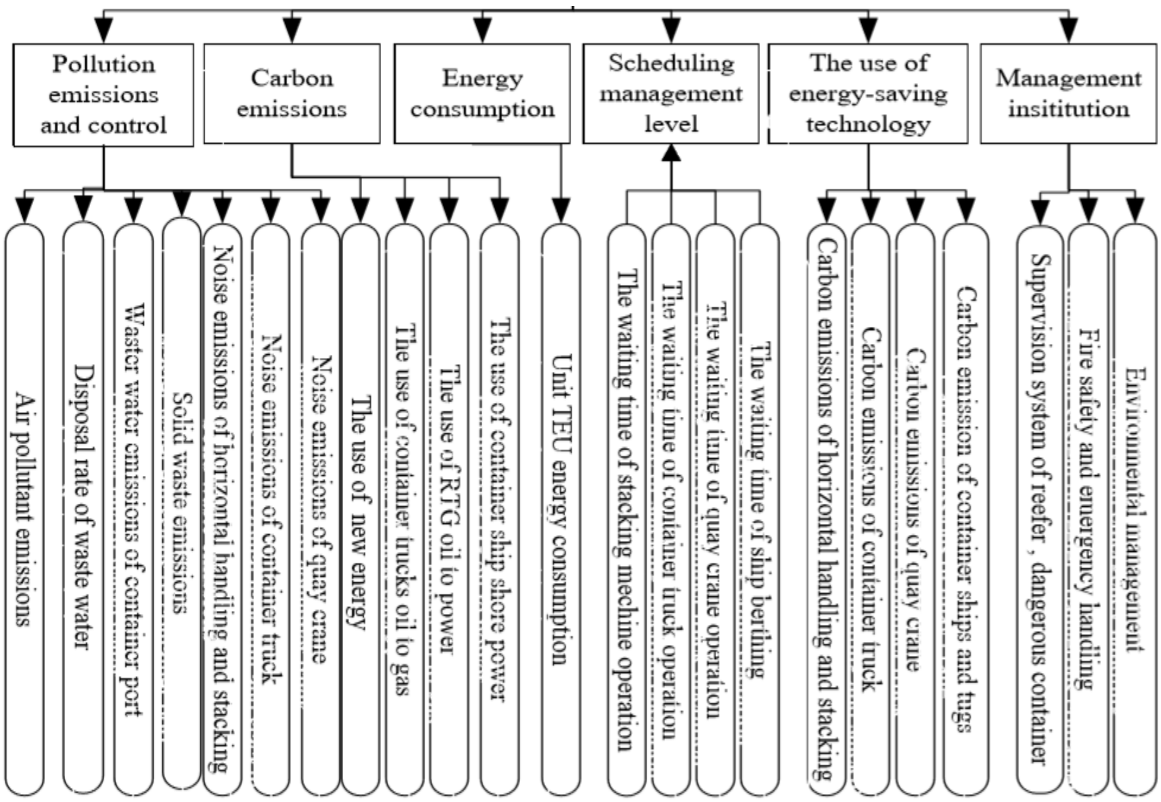


Figure 6.9 *Target system for green container port (Source: Analysis on low-carbon and green container port building goal system)*

6.6.1 Air pollution

Many of the most polluting sources of air pollution are concentrated in marine ports, often creating serious effects on the health of industrial and urban air pollution. For example, seaports attract hundreds of huge ocean-going ships and tugs, which burn the dirtiest available diesel fuel. The cargo is moved from the shipyards with fleets of highly polluting heavy equipment and is delivered and taken away from those shipyards by millions of heavy container trucks and locomotives, many of which were built well before the emission standards.

Atmospheric pollutants emitted by port-related activities negatively affect the health of port workers and residents of neighbouring communities and contribute significantly to regional air pollution problems.

The main air pollutants related to port activities that can affect human health include nitrogen oxides (NO_x), sulfur oxides (SO_x), ozone particles (O_3), diesel exhausts and volatile organic compounds (VOC). Other pollutants from port operations - such as carbon monoxide (CO), formaldehyde, heavy metals, dioxins and even pesticides used to fumigate products - can also be problematic.

The vast majority of the equipment used in ports today works with diesel, emitting a toxic mixture of particles, vapours and gases, including NO_x, VOC and SO_x. In addition to the pollutants listed above, diesel exhaust gas contains an estimated total of 450 different compounds, about 40 of which are considered to be toxic air contaminants with adverse effects on health and the environment.

Many studies have shown that diesel exhaust gases can irritate the nose, breasts, throat and eyes and damage the lower respiratory tract.

Studies on people exposed to diesel exhaust have documented eyes and nose irritation, bronchitis, cough and phlegm, wheezing, and deterioration in the ability to take full, deep breaths.

Although difficult to quantify, maritime transport emissions have increased over the last fifty years. Greenhouse gases and conventional pollutants contribute to the greenhouse effect and derive mainly from the combustion of fuel.

It is appropriate to mention the GHGs.

Emissions of greenhouse gases, including CO_2, methane (CH_4) and nitrous oxide (N_2O), from maritime transport, contribute significantly to global anthropogenic air pollution. In 2012, total transport emissions amounted to 961 million tons of CO_2.

Bulk carriers, oil tankers and container ships are responsible for most of the greenhouse gases derived from transport (Figure 6.10). While HFO fuels (heavy fuel oil) and MDO (marine diesel oil) emit similar levels of greenhouse gas pollutants, LNG (liquefied natural gas) can reduce CO_2 emissions by ~ 25% but has higher emissions than CH_4, which is a powerful greenhouse gas. Despite this, LNG is considered a fuel for emerging maritime transport.

Increased CO_2 deposition and ocean absorption of maritime transport exacerbate environmental extremes caused by climate change, so strategies to reduce emissions are urgently needed.

Just to have an idea about the sources of air pollution in ports could be, mainly:

- marine vessels emissions;
- cargo handling equipment emissions;
- heavy trucks transporting cargo to and from ports emissions;
- trains that have accessibility in the port terminal (railway traffic);
- loading and unloading of goods that produces volatile organic compound emissions;

- dry docks (evaporative volatile organic compound emissions);
- car traffic inside the port (combustion products and evaporative volatile organic compound emissions);
- demolition or main modification of ships (heavy metals, hydrocarbon, asbestos).

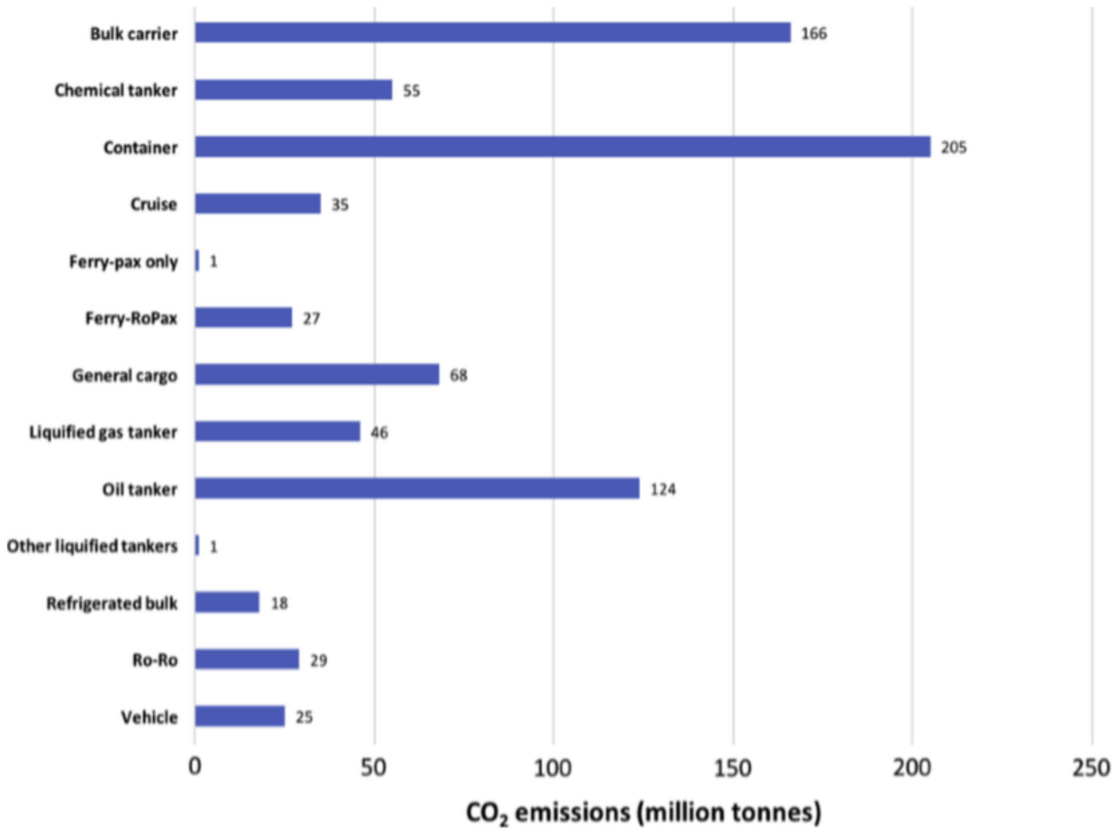


Figure 6.10 *CO_2 emissions from different type of maritime transportation (Source: Environmental effects of maritime transportation)*

6.6.2 Water pollution

Waste from ships, either dumped directly or leached into the water, can cause significant damage to water quality, and subsequently to marine life and ecosystems and human health. These effects may include bacterial and viral contamination of commercial fish and shellfish, depletion of oxygen in water, and bioaccumulation of certain toxins in fish.
Oily bilge water is one major pollutant from ships. Water collected at the bottom of the hull of a ship, known as the bilge, is often contaminated by leaking oil from machinery. This bilge water must be emptied periodically to maintain ship stability and to prevent the accumulation

of hazardous vapours. This oily wastewater, combined with other ship wastes, including sewage and wastewater from other onboard uses, is a serious threat to marine life.

Other pollutants from ships are the antifouling additives used in the paint on ships to prevent the growth of barnacles and other marine organisms on ship surfaces. Some of these additives contain tributyltin (TBT), a toxic chemical that can leach into the water.

In shipyard workers, TBT has been linked to skin irritation, stomach aches, colds, influenza, and such neurological symptoms like headaches, fatigue, and dizziness.

While toxic antifouling additives are slowly being phased out of use, these toxic pollutants persist in the marine environment. Environmentally safe alternatives to TBT are widely available. They include copper-based and tin-free antifouling paints, non-stick coatings that provide a slippery surface on which organisms cannot attach, prickly coatings that also prevent attachment.

Source of water pollution could be, mainly:

- oil spill;
- operations on terminals and fuel deposits (accidental discharge of liquefied substances loss from deposit tankers and pipeline);
- dry dock operations (accidental discharge of oil and other chemicals in the sea);
- ships demolition (accidental discharge of toxic substances in the sea);
- stormwater runoff from port parking lots (organic compounds, fine particulate, heavy metals, etc.);
- water thermal pollution;
- water stagnation and eutrophication and anoxia risks due to weak water turnover;
- dredging operations;
- ballast water.

6.6.3 Noise pollution

With machines, trucks, and ships, quay operations equipment (crane, fork-lift, straddle carriers, etc.), operating 24 hours per day ports can be loud.

The noise pollution from port activities, in addition to being annoying, can have serious negative health effects.

Noise pollution has been linked to hearing impairment, high blood pressure, sleep deprivation, reduced performance.

Additionally, noise from ship engines may disturb marine mammal hearing and behaviour patterns, as well as bird feeding and nesting sites.

With those dangers in mind, several ports are taking steps to reduce noise pollution.

The major noise sources in a ship are the main propulsion machinery, the auxiliary engines, the propeller and transverse propulsion unit, and the heating, ventilation and air conditioning system. The majority of main and auxiliary machinery is driven either by diesel engines or steam turbines. These last generate less noise than diesel engines with similar output power. Machinery generates noise into the surrounding air and also induces vibration into any structure to which it is connected. Noise transmission can either be waterborne, airborne or structureborne. The most important noise for the port area is the airborne noise and particularly the ambient noise in outdoor areas.

The main sources of noise pollution could be:

- car and heavy vehicles (trucks) road traffic (the most important one);
- goods movement (cranes, pumps, other operations machineries);
- rail traffic noise (rail movement in port and in surrounding areas are prevalent to low speed and of consequence, the noise level is not so high, however in highly trafficked areas the problem can be relevant);
- ships movements (engine, vibrations, fans, propellers, etc.).

6.6.4 Resource consumption

As far as this type of attribute is concerned, it is worth remembering, as can be seen from the table (Table 6.4) in which all the attributes are reported, that it collects more than one meaning. According to our research, more than one class of elements that define their existence adhere to the specification of this attribute.

We are talking about resource consumption interpreted as:

- electricity consumption
- water consumption
- fuel consumption
- waste creation and disposal

- provision of adequate facilities for the treatment of LNG (here a resource consumption is generated that generates waste thanks to the phases that govern the treatment of LNG, as previously reported in the summary table of attributes).

Not going into the details of what concerns fuel consumption which seems to have a fairly obvious meaning (any vehicle that operates in the port subject to diesel movement naturally consuming fuel produces emissions), it would be more appropriate to talk about electricity consumption and the generation of waste.

As regards the first, it can, of course, be remembered that the consumption of electricity is linked to all the operations that require a power supply in the port. So, we're talking about operations that can range from simple daytime and night-time port lighting to the power supply provided to ships when they dock at the port (OPS, Onshore Power Supply). In fact, "Ground Power Unit" GPU (on-ground feeders) are used to power the ships with the engines off. The electric power supply of the ships in the ports is necessary in order however to allow, for those on board, to be able to carry out any type of action that requires current.

Other electricity consumption is naturally linked to the rest of the port activities (operation of dockside machinery, operation of transtainers, operation of other equipment, etc.).

As for the category of waste creation, it must be said that it is unlikely to quantify the production of waste (more than anything solid) that can be produced in a port. This, in effect, depends on many variables, first of all, the number of ships operating in the port itself.

It was possible, thanks to a careful review of the literature, to divide the category of waste creation and treatment into two very important classes. That of urban waste and that of harmful waste (as can be seen from the table relating to the attributes found).

Another relevant class in which this parameter has been divided is that of soil pollution with its consequent generation of waste. The quality of the soil that surrounds a port is one of the many problems that affect the quality of life in human settlements near ports (parameter included in the major attribute of port environmental improvement and development).

6.6.5 Port capacity and productivity

This is the first of the attributes we can define as the management attribute. In this attribute, we tried to put together all those factors that collaborate and trying to improve the competitiveness of a port on the international scene.

Obviously, all the necessary elements that contribute to the development of ever-higher productivity and capacity indices have been considered.

According to our research the most important are:

- supply at port berth (OPS);
- availability of feeder facilities;
- provision of any kind of service;
- congestion (waiting time and delay); it involves berthing dwell time and times for loading and unloading goods according to equipment's availability;
- capacity to store and handle hazardous cargoes (ports need specific permissions to do that);
- capacity to manage a big volume of traffic (here we talk about port efficiency and capacity);
- experience and readiness of port (includes the responsibility for personnel, customs clearance, good workers' preparation, relationships between administrative management side and operation work side);
- restrictions on handling goods and restrictions in possibilities of port operations (it involves restrictions on handled goods, work hours to load and unload, forbidden operations);
- quality of the requested services (any kind of service requested by ship from berths' immediate availability to the security of operations made and security of workplace conditions).

6.6.6 Port environmental improvement and development

This is the second of the attributes we can define as the management attribute.

As widely described in the ESPO report of 2018, the management factors that significantly influence the concept of port greening are manifold.

Specifically, this attribute has collected all those aspects that would lead to a port greening concept from a purely administrative and not purely environmental point of view.

ESPO has already defined many of the points that will be touched in the specification of this attribute.

We find:

- existence of a certified Environmental Management System (EMS);
- existence of Environmental Monitoring Programme (EMP);
- existence of environmental policy and legislation;
- presence of an Environmental Inventory of Significant Aspects (SEA);
- targets for environmental improvement and development (in land-side and sea-side);
- geographical advantages;
- relation with communities and human settlements.

The first four elements comings from regulations and every port can have its own regulation issued from Port Authority, mostly. These elements are needed to regulate specific situation (risk, emergency, threat, danger, hazard, disaster, alert, eventuality, etc.)

6.6.7 Cost and charges

It is fair to recall that the costs, although not an actual environmental indicator, are included in an analysis of this kind because in one way or another they influence the behaviour of the shipping companies in the choice of the port where to land.

The cost parameter appears to be an element of fundamental importance, therefore, in the companies' decision and precisely, for this reason, the contribution that this provides to the analysis carried out is decisive. The costs to be borne by maritime companies within a port are manifold and can be divided in various ways.

Various amendments have been issued over the years that establish the costs that must be incurred in a port. There are various factors that affect the determination of port prices and of course at the same time there are limits that determine the extent of these costs. Based on a study carried out by UNCTAD, the situation just mentioned is illustrated, noting through a figure (Figure 6.11) what are all the major operations that require costs for shipping companies within a port. To the costs of all the operations shown in the image, must naturally be added all the administrative costs to which a company is subject to adapt in the case of berthing in a port.

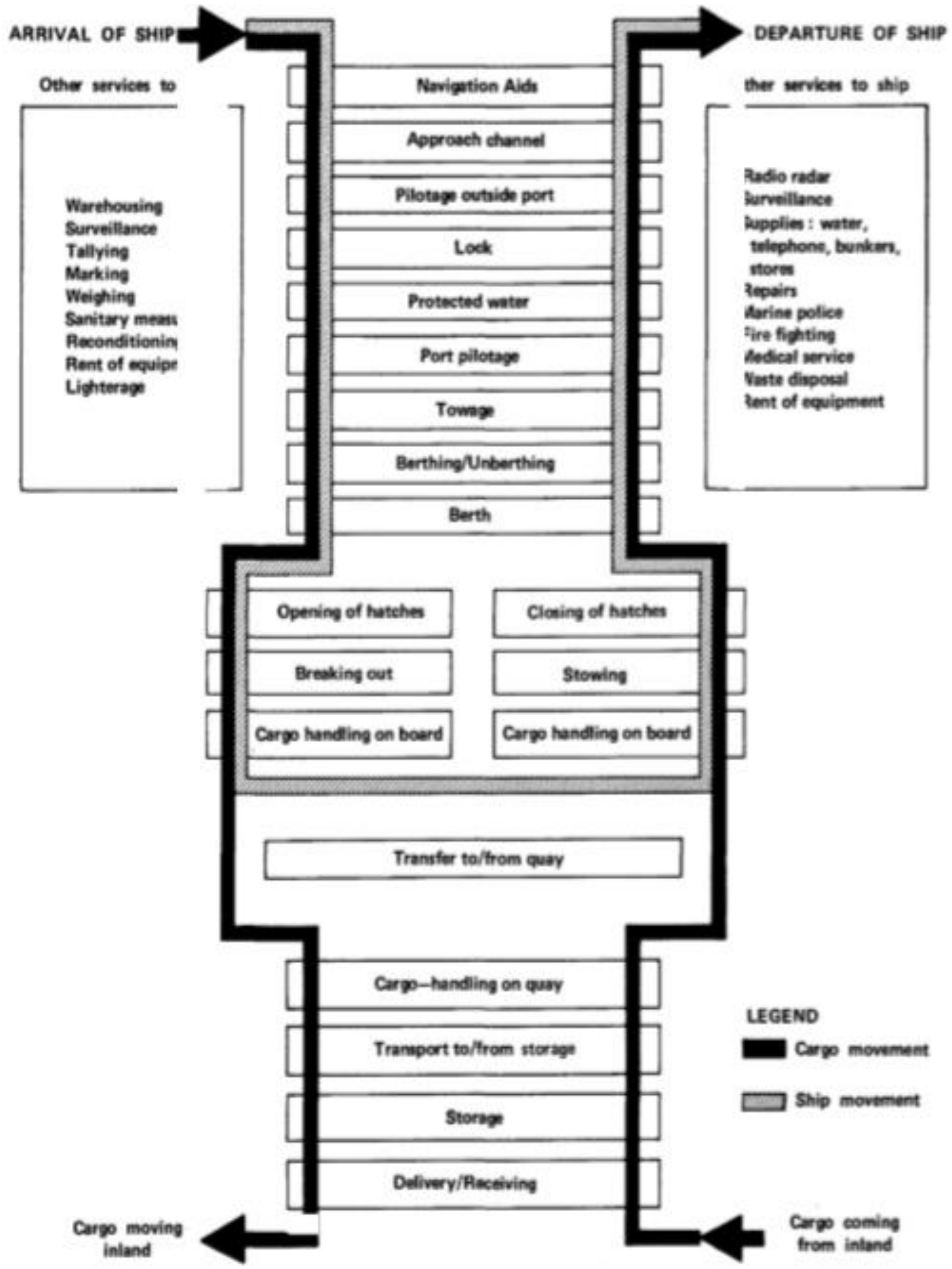


Figure 6.11 The movement of cargo and ships in a port: main facilities and services provided by a port that a company must pay (Source: Port pricing UNCTAD secretariat)

7 GENERATION OF THE EXPERIMENTAL DESIGN

7.1 Definition of attributes' levels

The first step to proceed to the generation of the design is to define the attribute levels.

This step is also essential to be able to describe the design approach from a formal point of view. In fact, in the next paragraphs, we will deal with the specific characteristics of the generated design that presuppose the knowledge of the levels of attributes.

We also remind you that there are two alternatives we have decided to introduce to make the choice (Port A and Port B).

According to a detailed analysis of the literature of the discrete choice experiments, the levels to assign to the attributes are the following:

COST AND CHARGES (5 levels): any kind of port dues and general charges (for any kind of service),

- 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 (5 levels): atmospheric emissions, GHGs, odours problems checked in port,

- 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 (3 levels): noise caused by any kind of activity in port,

- 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 (3 levels): contaminant events which harm the water quality,

- 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 (5 levels): energy, fuel and water consumption and related waste creation,

- 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 (3 levels): any kind of element useful to develop capacity and measure the degree of productivity in port,

- 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 (3 levels): aspects related to the management and administration of environmental systems and its related field,

- 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)**.

7.2 Full factorial and fractional factorial design

A question that needs to be discussed is which type of design should be used. In general, there are two groups of selected drawings:

- the complete factorial design, with all the possible choice situations given a particular number of attributes and levels;
- the fractional factorial designs, in which only a part of all possible choice situations is included.

The disadvantage of all the factorial projects is that often when working with a fairly large number of attributes (which exceeds 3), too many combinations are obtained. In fact, with seven attributes as in our case, three of which with 5 levels and 4 with 3 levels, the number of different combinations of levels that can be generated is ($5 \cdot 5 \cdot 5 \cdot 3 \cdot 3 \cdot 3 \cdot 3 = 5^3 \cdot 3^4 = 10125\ levels$). This situation, when working with two choice alternatives (Port A and Port B), becomes very complex to manage, because it would come to work with a multitude of combinations. This is much more than a respondent can handle. Therefore, complete factorial projects are useful only for problems involving very few attributes and/or levels.

For problems with multiple attributes and/or levels, a fractional factorial design is more convenient. In a fractional factorial design, only a series of possible combinations are maintained.

In light of what has just been shown, in our experiment, it was decided to work with a fractional factor design.

7.3 Labelled and unlabelled choice experiments

At this point, we need to define the choice set and therefore to determine how many alternatives to submit to individuals for their choice.

Our experiment is carried out by submitting to individuals two unlabelled alternatives for each choice.

Experiments that use generic titles for alternatives are called unlabelled experiments.

The decision to use labelled or unlabelled experiments is important for the design generation because.

One of the main advantages of using unlabelled experiments is that they do not require the identification and use of all alternatives within the universal set of alternatives.

To explain, we note that a label associated with an alternative act in some way as a further attribute for the alternative one, going to significantly influence, more often than not, the choice of the interviewee.

7.4 Bayesian Optimal Design[22] consideration

[22] In simpler terms, Bayes' theorem provides a method to modify the level of trust in a given hypothesis, in the light of new information. Denoting with H_0 the null hypothesis, and with E the observed empirical data, the Bayes theorem can be stated as:

$$P(H_0|E) = \frac{P(E|H_0)P(H_0)}{P(E)}$$

Leaving aside the origin of the null hypothesis (which may have been formulated ab initio, or deduced from previous observations), it will still have to be formulated before the observation E. In the Bayesian statistic terminology, moreover:

- $P(H_0)$ is called a priori probability of H_0
- $P(E|H_0)$ is called the likelihood function, and it is what the classical or frequentist inference is based on;
- $P(E)$ is called marginal probability, the probability of observing E, without any previous information; it is a normalization constant;
- $P(H_0|E)$ is called a posteriori probability of H_0, given E.

Two well-known fractional factorial designs are orthogonal designs and Bayesian[23] optimal design (also called efficient designs). The orthogonal designs are created with the aim to minimize the correlation between the attribute levels in choice situations.

Efficient designs, on the other hand, have the purpose of maximizing the information from each choice situation. They exclude, for example, choice sets in which one alternative which includes the most unattractive attribute levels is compared with an alternative with only the most attractive levels. Such a choice would reveal no information to the researcher as the decision of every respondent would be known beforehand.

For determining the most efficient design, the D-error is one of the most widely-used criteria, which leads to so-called D-optimal designs. However, to be able to determine the D-error, the part-worths (estimates) of the attributes have to be known a priori.

As we do not have those, three different paths can be followed.

First, educated guesses can be made for the values of the part-worth, which leads to so-called locally D-optimal design. But this one is not our choice.

Second, the part-worths can be assumed to be 0, which leads to utility neutral design. This assumption, however, is highly unrealistic as it assumes that respondents do not have preferences.

The third and most robust path is to assume the part-worths to follow a specific distribution, which leads to so-called Bayesian D-optimal designs.

In this study, we did not resort to Bayesian D-optimal design, since, as mentioned, there was no possibility of having previous information (probability distributions and probability density)

Bayesian experimental design provides a general probability-theoretical framework from which other theories on experimental design can be derived. It is based on Bayesian inference to interpret the observations/data acquired during the experiment. This allows accounting for both any prior knowledge on the parameters to be determined as well as uncertainties in observations.

The theory of Bayesian experimental design is to a certain extent based on the theory for making optimal decisions under uncertainty. The aim when designing an experiment is to maximize the expected utility of the experiment outcome. The utility is most commonly defined in terms of a measure of the accuracy of the information provided by the experiment (e.g. the Shannon information or the negative variance) but may also involve factors such as the financial cost of performing the experiment. What will be the optimal experiment design depends on the particular utility criterion chosen.

[23] Bayesian inference is an approach to statistical inference in which probabilities are not interpreted as frequencies, proportions or similar concepts, but rather as levels of confidence in the occurrence of a given event. The name derives from the Bayes theorem, which is the foundation of this approach.

Bayes' theorem is named after the Reverend Thomas Bayes. However, it is not clear if Bayes himself would subscribe to the interpretation of the probability theory that we now call Bayesian.

regarding the attributes involved. In fact, it is such an experiment had never been conducted before.

It was not even wanted, for reasons of difficulty and time, to resort to the formulation of Bayesian optimal models through exploratory interviews conducted a priori by the interviewees.

As can be seen below, in fact, we will not have any previous data (prior mean values) and therefore we will not be able to generate any prior variance matrix.

The advantage that would have brought a Bayesian D-optimal design would have been that, through a prior distribution of probability, to avoid situations of choice in which a profile is completely dominant on the other profile on each attribute.

Just to be precise and report a short description of what Bayesian D-optimal design means, is shown below the construction.

7.5 JMP Pro 14 and choice experiment design

Figure 7.1 *JMP logo (JMP website download)*

Statistical software produced by SAS Institute[24] has been used for the design generation; it is JMP Pro 14. JMP (pronounced "jump") is a suite of computer programs for statistical analysis developed by the JMP business unit of SAS Institute. It was launched in 1989 to take advantage of the graphical user interface introduced by the Macintosh. It has since been significantly rewritten and made available for the Windows operating system. JMP is used in applications

[24] SAS Institute (or SAS, pronounced "sass") is an American multinational developer of analytics software based in Cary, North Carolina. SAS develops and markets a suite of analytics software (also called SAS), which helps access, manage, analyze and report on data to aid in decision-making. The company is the world's largest privately held software business.

such as Six Sigma, quality control, and engineering, design of experiments, as well as for research in science, engineering, and social sciences.

The software can be purchased in any of five configurations: JMP, JMP Pro, JMP Clinical, JMP Genomics and the JMP Graph Builder App for the iPad. The software is focused on exploratory visual analytics, where users investigate and explore data. These explorations can also be verified by hypothesis testing, data mining, or other analytic methods. In addition, discoveries made through graphical exploration can lead to a designed experiment that can be both designed and analyzed with JMP.

For the generation of design, two phases were fundamental.

The first phase was one in which, once the attributes had been selected, it was possible to proceed by inserting them into the software, generating a first part of the choice design.

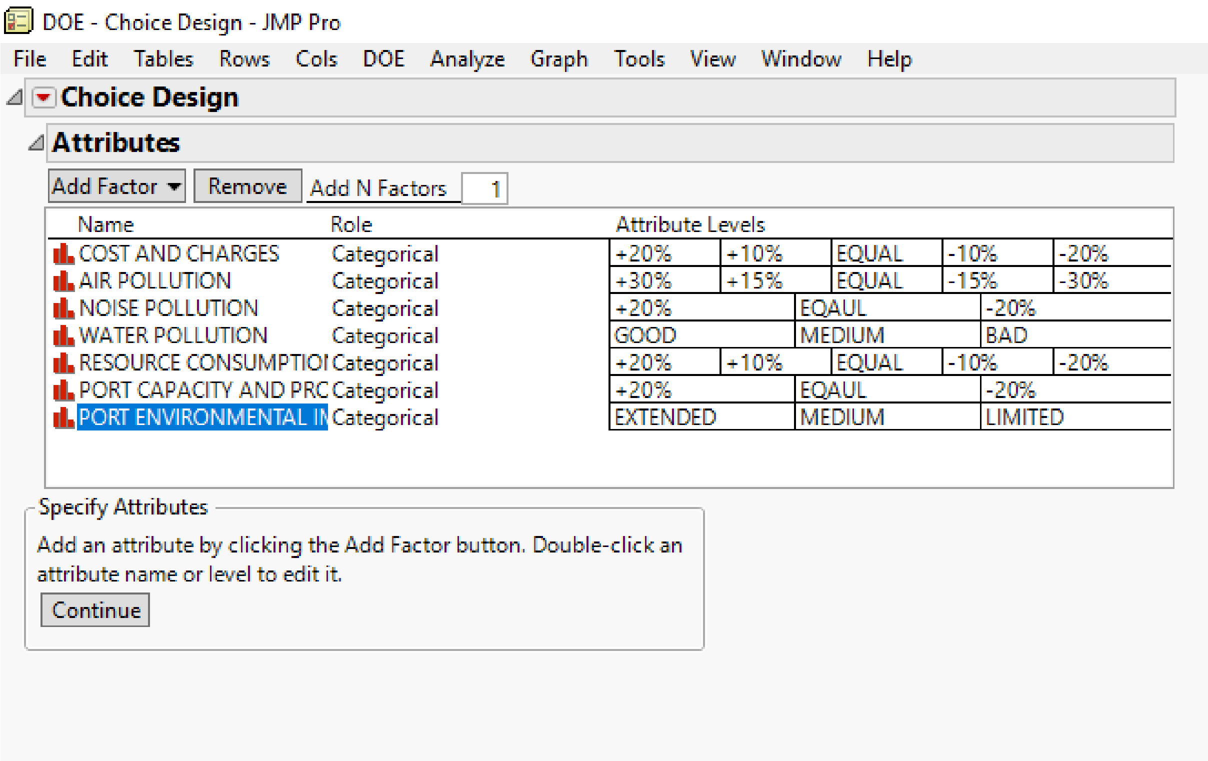


Figure 7.2 *JMP attributes and levels definition in choice design (Source: JMP)*

This first phase ends when, once the procedure has been started (by clicking on continue), it can be seen how the software indicates whether to work or not with prior values (prior mean values and prior variance matrix).

Of course, since we do not have these values, our choice will fall on a matrix of variance practically equal to the identity matrix. This means that we will not enter any previous data. It can be seen what just described:

Prior Specification

☐ Ignore prior specifications. Generate the Utility Neutral design.

Prior Mean

Effect	Prior Mean
COST AND CHARGES 1	0,000
COST AND CHARGES 2	0,000
COST AND CHARGES 3	0,000
COST AND CHARGES 4	0,000
AIR POLLUTION 1	0,000
AIR POLLUTION 2	0,000
AIR POLLUTION 3	0,000
AIR POLLUTION 4	0,000
NOISE POLLUTION 1	0,000
NOISE POLLUTION 2	0,000
WATER POLLUTION 1	0,000
WATER POLLUTION 2	0,000
RESOURCE CONSUMPTION 1	0,000
RESOURCE CONSUMPTION 2	0,000
RESOURCE CONSUMPTION 3	0,000
RESOURCE CONSUMPTION 4	0,000
PORT CAPACITY AND PRODUCTIVITY 1	0,000
PORT CAPACITY AND PRODUCTIVITY 2	0,000
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT 1	0,000
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT 2	0,000

Figure 7.3 *JMP prior mean values specification (Source: JMP)*

What about the prior variance matrix we show (Figure 7.4) just the first part because it was so large and there was not enough space to use to report it:

Prior Variance Matrix

Effect	COST AND CHARGES 1	COST AND CHARGES 2	COST AND CHARGES 3	COST AND CHARGES 4	AIR POLLUTION 1	AIR POLLUTION 2	AIR POLLUTION 3	AIR POLLUTION 4	NOISE POLLUTION 1	NOISE POLLUTION 2	WATER POLLUTION 1
COST AND CHARGES 1	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
COST AND CHARGES 2		1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
COST AND CHARGES 3			1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
COST AND CHARGES 4				1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
AIR POLLUTION 1					1,000	0,000	0,000	0,000	0,000	0,000	0,000
AIR POLLUTION 2						1,000	0,000	0,000	0,000	0,000	0,000
AIR POLLUTION 3							1,000	0,000	0,000	0,000	0,000
AIR POLLUTION 4								1,000	0,000	0,000	0,000
NOISE POLLUTION 1									1,000	0,000	0,000
NOISE POLLUTION 2										1,000	0,000
WATER POLLUTION 1											1,000
WATER POLLUTION 2											
RESOURCE CONSUMPTION 1											
RESOURCE CONSUMPTION 2											
RESOURCE CONSUMPTION 3											
RESOURCE CONSUMPTION 4											
PORT CAPACITY AND PRODUCTIVITY 1											
PORT CAPACITY AND PRODUCTIVITY 2											
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT 1											
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT 2											

Figure 7.4 *JMP prior variance matrix as an identity matrix (Source: JMP)*

The second phase, on the other hand, involves the actual generation of the design by specifying the following features:

- 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 we can give life to what, as widely described above, is nothing other than the definitive combination of the attributes with the respective levels (which we have defined as being partial or even the result of a fractional factorial design).

Obviously, the combinations generated by the software will be random combinations. This means that if you wanted to set the design more than once, the same combinations might not always be generated, rather they would always be different.

In the next figure (Figure 7.5) we illustrate the procedure adopted, with the exact data:

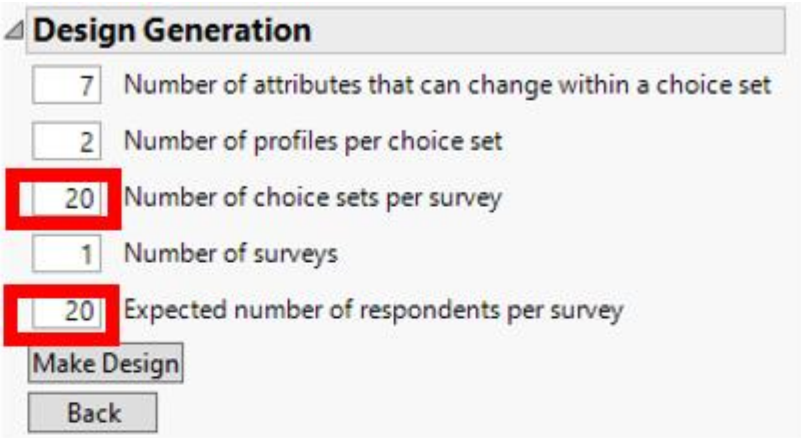


Figure 7.5 *JMP design generation final phase (Source: JMP)*

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, or 7, to establish 20 questions to be introduced in the questionnaire.

At the same time, as will be seen below, 20 possible questionnaire respondents have been established. This number is the number of companies that will actually be contacted.

As you can see, for the rest of the sections, as we already knew from what has been described so far in the report, 2 alternatives of choice have been established (Port A and Port B; it has already been specified that these are alternatives unlabelled), 1 only questionnaire and confirmation of 7 attributes.

As we said, the software generates random combinations to build the survey. In our case, the combinations obtained are the following reported in Appendix A.

7.6 Questionnaire design

After obtaining the random combinations of the available attribute levels, mentioned in Appendix A, 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 in question, the cornerstone of the questionnaire, in our research, is: "***how do container shipping companies choose their ports for cargo operations, taking account port greening concept as much as possible?***"

The goal of the whole analysis, as we already know, 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 huge control on the willingness and decision to choose which port to dock or not by a shipping company.

The questionnaire has been built using a software called Qualtrics, which helped to set up and fix the framework. It is composed of 21 questions. The first one below in figure (Figure 7.6).

20 of that are what we already know as "choice set", and the last one, the 21st, is an open question.

The first 20 choice set has the same request at the basic, 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?*"

QUESTION 1

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?

	• 10% higher port charges • 30% lower air pollution • 20% lower noise pollution • Average restrictions on water pollution • Equal port resource consumption compared with the current situation • Equal port capacity and productivity compared with the current situation • Low degree of development and improvement	• Equal port charges compared with the current situation • 15% lower air pollution • 20% lower noise pollution • Average restrictions on water pollution • 20% higher port resource consumption • 20% higher port capacity and productivity • Low degree of development
	PORT A	***PORT B***
	○	○

Figure 7.6 *Question 1 of the survey (Source: own composition)*

In every choice set changes the profile thanks to the alternation of random combinations of indicators variations. Every interviewee had to read the questionnaire and upon its opinion had to answer or to choose the most suitable alternative between Port A and Port B.

What about the last question, the 21st, it is an open question. It has been specified in the description of the questionnaire presented to the interviewees, that this 21st question would have been optional. Unfortunately, as we will see in the following chapters, in our case, not everyone answered that question.

Just to have an example, here, below, in the table (Table 7.1) the first choice set of the questionnaire is shown. The whole questionnaire is shown in Appendix B, in the faithful way it has been distributed to the shipping companies.

It is important to underline the correspondence between the first choice set of the combination given before (Figure 7.6) and here reported in the following table and the framework of the first question in the questionnaire.

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

Table 7.1 *First choice set (Source: own composition)*

8 DATA COLLECTION AND RESULTS ANALYSIS

8.1 Data collection

The experiment of discrete analysis continues with a fundamental phase which is that of data collection.

The questionnaire illustrated above was administered to the selected shipping companies in the period that went from March 29th to May 24th 2019.

The companies contacted are all shipping companies that have their offices in the port of Antwerp. They are among the most important maritime companies in the world.

The procedure with which these investigations were carried out was guided through some phases.

The first phase 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 our data. The second phase was, of course, the expectation of their response to our request.

The third phase was the questionnaire administration to the partners who agreed to collaborate with us.

A total of 14 companies collaborated on our project.

The interviews, as specified in the abstract of this document, were conducted in three different ways:

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

Of the 14 companies interviewed, 13 explicitly requested that their response profiles not be made public, for privacy reasons. Then in the analysis, the results obtained from the questionnaire will be reported without mentioning the name of the respondent company.

A single company has agreed to make its response profile public and we will see later that it will be Arkas Lines.

Here below in the table (Table 8.1) the whole list of the 20 companies contacted for the collaboration; it is specified the name of the company, the nationality of the company, the data of the interview and the acceptance of the collaboration or not. It is not reported the directed person contacted to obtain the collaboration for a privacy matter:

Shipping Company	Nationality of the company	Data of the interview	Acceptance of the collaboration
APM Maersk	Denmark	02-04-2019	YES
MSC (Mediterranean Shipping Company)	Switzerland	07-05-2019	YES
COSCO Group (China Ocean Shipping Company)	China	02-05-2019	YES
CMA-CGM Group	France	12-04-2019	YES
Hapag-Lloyd AG	Germany	15-05-2019	YES
Evergreen Marine Corporation	Taiwan	-	NO
Yang Ming Marine Transport Corporation	China/Taiwan	20-05-2019	YES
HMM (Hyundai Merchant Marine)	South Korea	10-05-2019	YES
OOCL Orient Overseas Container Lines	Hong Kong	10-04-2019	YES
Arkas Container Transport Line	Turkey	30-04-2019	YES
X-Press Feeders Group	Singapore	18-04-2019	YES
Grimaldi Group	Italy	24-05-2019	YES
StreamLines (Sea-trade BV)	Scotland	22-04-2019	YES
ZIM (Integrated Shipping Services Ltd.)	Israel	26-04-2019	YES

ONE (Ocean Network Express)	Singapore/Japan	29-03-2019	YES
Wan Hai Lines	Taiwan	-	NO
Nile Dutch (The Africa Connection)	Netherlands	-	NO
Hamburg Sud	Germany	-	NO
TMCL Container Line	Belgium	-	NO
Samskip	Netherlands/Iceland	-	NO

Table 8.1 *Shipping Companies contacted for the collaboration (Source: own composition)*

In Appendix C are reported the results of the questionnaire, and, as we said before, just one example of the questionnaire response, given and provided from Arkas Lines, the only one didn't specify privacy request.

8.2 Results analysis

The phase following the data collection was to insert them in the JMP software used for our calculations and for the generation of our analysis model.

The results obtained from the questionnaires administered to the various companies were entered in a JMP worksheet in which they were processed and reordered. They were all conducted within a work table that we called "Selection Attempts" and from this table was then developed the next step of elaboration of the model.

Of course, as previously mentioned in the other chapters, the model used to analyze these results was a Multinomial Logit Model (MNL), which uses JMP. It was not considered appropriate, in terms of time, to analyze the results with other statistical calculation systems such as N-logit and Biogeme.

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 the figure below (Figure 8.1) is possible to see how the analysis of the data could start.

In a choice model window is presented the table "Selection Attempts" with all its elements. Under the voice "Select Columns" are indicated all the elements present in the table considered. In the voice of "Pick Role Variable" are indicated all the significant elements to be selected needed to run the model.

Next step is to go to select these elements from those reported in the voice "Select Columns", as it is shown, after (Figure 8.2).

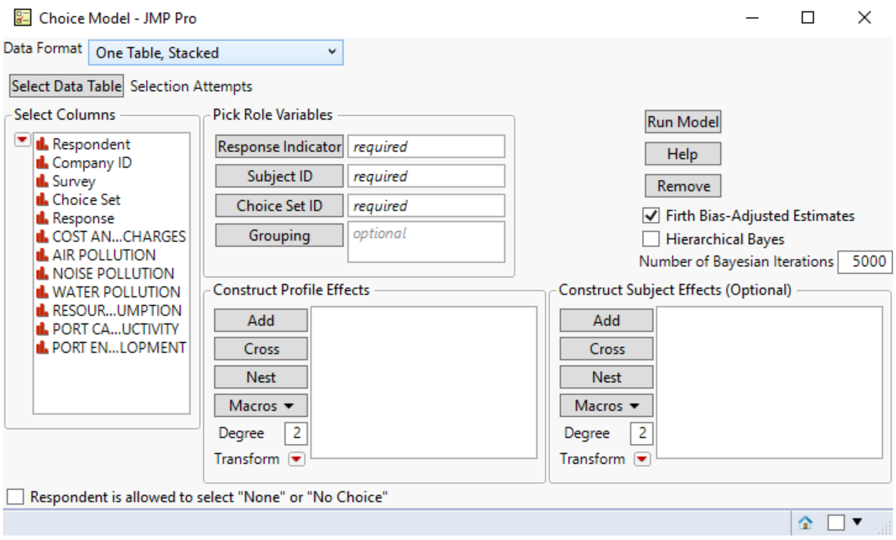


Figure 8.1 *Choice Model window to select the elements to run the model (Source: JMP)*

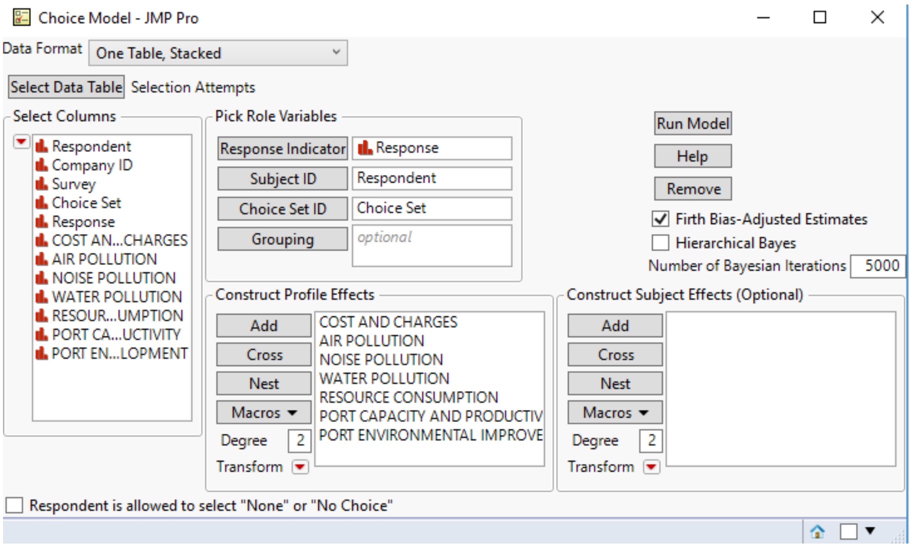


Figure 8.2 *Choice Model window: Pick Role Variables chosen to run the model and attributes selection (Source: JMP)*

As it is possible to see, the various elements necessary to implement the model have been selected in the "Pick Role Variables" entry.

In the "Response Indicator" section the "Response" parameter was selected, which is of fundamental importance in the generation of the model, while in the other two sections "Subject ID" and "Choice Set ID" the parameters "Respondent" and "were selected Choice Set ".

You can certainly see in the window that there is a second entry, the "Construct Profile Effects". In this section, all the attributes available in the "Selection Attempts" table (or window as you prefer) have been selected.

The voices concerning the "Grouping" have been left empty instead, an optional section that does not concern the analysis that we went to perform, as well as the "Construct Subject Effects", also this optional section that was not involved in our analysis.

Of course, we do not select the "Hierarchical Bayes" box as specified in the previous pages regarding the generation of the model, and instead, the "Firth Bias-adjusted elements" box is selected by default (and maintained by us), which we will see later what it means.

By clicking on the "Run Model" box, the first interpretation of the data obtained is finally obtained.

We get a first overview in which the effects of our results are summarily shown. It's called "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 FDR[25] (False Discovery Rate) Log-Worth) values for these effects.

The “Effect Summary” table contains the following columns:

- *Source*

Lists the model effects, sorted by ascending p-values.

- *Log-Worth*

Shows the Log-Worth for each model effect, defined as $-\log_{10} p - value$.

[25] The false discovery rate (FDR) is a method of conceptualizing the rate of type I errors in null hypothesis testing when conducting multiple comparisons. FDR-controlling procedures are designed to control the expected proportion of "discoveries" (rejected null hypotheses) that are false (incorrect rejections). In statistical hypothesis testing a type I error is the rejection of a true null hypothesis (also known as a "false positive" finding or conclusion), while a type II error is the acceptance of a false null hypothesis (also known as a "false negative" finding or conclusion). Much of statistical theory revolves around the minimization of one or both of these errors, though the complete elimination of either is treated as a statistical impossibility.

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. Is not fundamental in our research.

- *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.
The "Effect Summary" window is reported in the figure below (Figure 8.3):

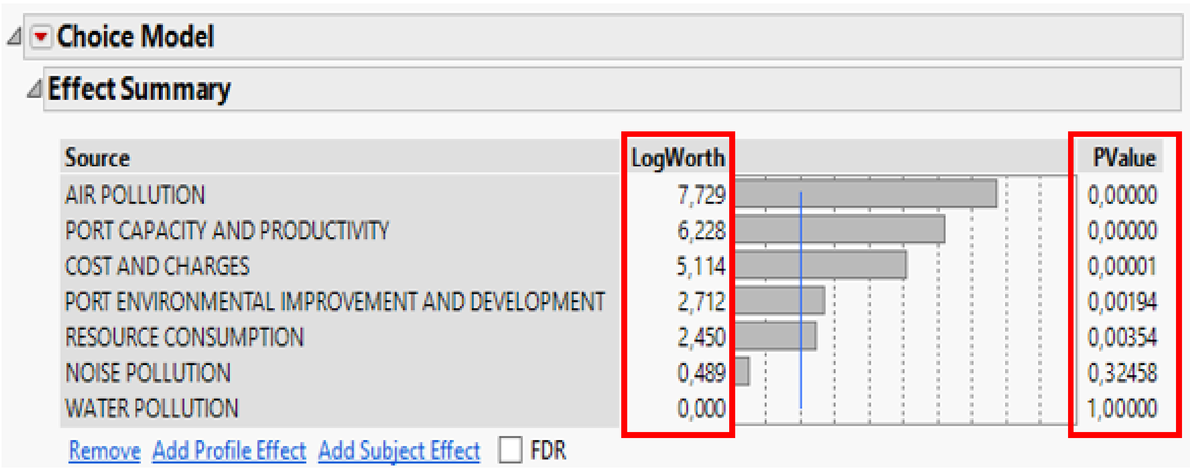


Figure 8.3 *Effect Summary window (Source: JMP)*

A second element found in the computed results is the "Parameter Estimates" window.
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*. When the Firth Bias-adjusted estimates option is selected in the launch window, the parameter estimates are based on the Firth bias-corrected maximum likelihood estimators. The is also a small window in which there are shown

the fit statistics that can be used to compare the models. Not considering the first AICs (Akaike's Information Criterion) and the second BIC (Bayesian Information Criterion), what is relevant for us is the $-2 \cdot Log(Likelihood)$ and $-2 \cdot Firth\ Log(Likelihood)$.

The $-2 \cdot Firth\ Log(Likelihood)$ fit statistic is included in the results when the Firth Bias-adjusted estimates option is selected in the launch window. Note that this option is checked by default. The decision to use or not use the Firth Bias-adjusted estimates does not affect the AICc score or the $-2 \cdot Log(Likelihood)$ results.

In the "Parameter Estimates" window in figure (Figure 8.4) is also reported the standard deviation error, which is not under our consideration for the analysis. It is an additional data.

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

AICc	304,56998
BIC	374,02253
-2*LogLikelihood	261,32673
-2*Firth LogLikelihood	204,42566

Figure 8.4 *Parameter Estimates window (Source: JMP)*

In logistic regression models, if the sample size is small or if a predictor is strongly associated with one of the possible outcomes, the estimated coefficients may be biased or separated.

One way to address the separation problem, for example, is to use "exact tests". However, in the case of logistic regression exact methods are only practical in very simple cases, where there is just one predictor. When additional (continuous) predictors are of interest, these methods are computationally intensive in terms of memory requirements and are rendered impractical.
Furthermore, exact methods adjust only the p-value, not the parameter estimates. An alternative approach is to use Firth's bias-adjusted estimates. In addition to being computationally efficient, Firth's method, which maximizes a penalized likelihood function, also guarantees that the parameter estimates will be finite (as opposed to the standard maximum likelihood estimates) and it corrects the parameters' distortions.
The third element found in the computed results is the "Likelihood Ratio Tests" window.
The meaning of likelihood ratio and likelihood ratio test has been already explained before in the other chapter, and here according to the figure (Figure 8.5) reported directly from JMP is possible to observe the following components:

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 8.5 *Likelihood Ratio Tests window (Source: JMP)*

Has to be noted:

- *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.

8.3 Results' interpretation

These first aspects of the results obtained are of fundamental importance and constitute our future interpretations.

First of all, it is necessary to report some theoretical considerations that will help to make the necessary observations for the continuation of the analysis of the results.

8.3.1 P-values as significative value

The *P* value, or calculated probability, is the probability of finding the observed, or more extreme, results when the "null hypothesis (H_0)" of a study question is true – the definition of 'extreme' depends on how the hypothesis is being tested. *P* is also described in terms of rejecting H_0 when it is actually true, however, it is not a direct probability of this state.

The null hypothesis is usually a hypothesis of "no difference". Must be defined a null hypothesis for each study question clearly before the start of your study. The "alternative hypothesis (H_1)" is the opposite of the null hypothesis; in plain language terms, this is usually the hypothesis you set out to investigate.

If your *P* value is less than the chosen significance level, then you reject the null hypothesis; you can accept that your sample gives reasonable evidence to support the alternative hypothesis. It does not imply a meaningful or important difference; that is for you to decide when considering the real-world relevance of your result.

The choice of significance level at which you reject H_0 is arbitrary.

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.

In the ideal world, we would be able to define a perfectly random sample, the most appropriate test and one definitive conclusion, but simply we cannot.

What is possible to do is try to optimize all stages of our 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).

8.3.2 L-R ChiSquare Test

We already know from the previous chapters the meaning of this parameter. What is reported in this section is a further clarification of this factor in order to comprehensively understand how data interpretation has been addressed.

In statistics, the likelihood-ratio test assesses the goodness of fit of two competing statistical models based on the ratio of their likelihoods, specifically one found by maximization over the entire parameter space and another found after imposing some constraint. If the constraint (i.e., the null hypothesis) is supported by the observed data, the two likelihoods should not differ by more than sampling error. Thus the likelihood-ratio test tests whether this ratio is significantly different from one, or equivalently whether its natural logarithm is significantly different from zero.

One of the likelihood-ratio tests is the ChiSquare test. It is a statistical hypothesis test where the sampling distribution of the test statistic is chi-squared distribution when the null hypothesis is true. So, with the ChiSquare test we mean one of the hypothesis tests used in statistics that use the chi-squared distribution to decide whether to reject or not reject the null hypothesis.

The chi-squared test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories. Practically, the ChiSquare test is widely used to verify that the frequencies of the observed values adapt themselves to the theoretical frequencies of a predetermined probability distribution.

The purpose of the test is to evaluate how likely the observations that are made would be, assuming the null hypothesis is true. ChiSquare tests are often constructed from a sum of squared errors, or through the sample variance. Test statistics that follow a chi-squared distribution arise from an assumption of independent normally distributed data. A chi-squared test can be used to attempt rejection of the null hypothesis that the data are independent.

Also considered a chi-squared test is a test in which this is asymptotically true, meaning that the sampling distribution (if the null hypothesis is true) can be made to approximate a chi-squared distribution as closely as desired by making the sample size large enough.

Just to have clearer the situation we could make an example out of the research.

Suppose that in a particular sample it has been observed that a set of possible events $E_1, E_2, \dots, E_k$ occurs with frequencies $o_1, o_2, \dots, o_k$ said observed frequencies, and that, according to the rules of probability, we expect that present with frequencies $e_1, e_2, \dots, e_k$ called theoretical or expected frequencies.

The ChiSquare test variable χ^2 is obtained by adding, for each event E_i the square of the differences between the theoretical frequencies and those observed weighted on the theoretical frequencies:

$$\chi^2 = \sum_{i=1}^{k} \frac{(o_i - e_i)^2}{e_i}$$

that, if the total number of events *N* is fixed, it is distributed as a variable χ^2 with *k-1* degrees of freedom otherwise if *N* is a random variable, for example Poisson's variable (as it can be in a counting experiment) it is distributed as a variable χ^2 with *k* degrees of freedom.

If the observed frequencies coincide exactly with the theoretical ones, then $\chi^2 = 0$, while if they differ, $\chi^2 > 0$. The larger the value of χ^2 the larger the discrepancy between the observed and the theoretical frequencies.

8.4 Effect Summary window interpretation

Having made these theoretical considerations, we can finally 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 our 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 go to see that the attributes that respect an index of probability values of this type and therefore are statistically very significant are respectively:

- air pollution;
- port capacity and productivity;
- cost and charges.

The other factors exceed this limit.

The assumption that we can make is that which concerns the fact that even if having a probability value just greater than 0.001, in fact, it is 0.00194, the port environmental improvement and development attribute can also be considered statistically significant in its probabilistic value.

The rest of the attributes that we cannot consider, according to our assumption, statistically significant, 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.

The work that will be done on these attributes will be addressed in the next paragraph**.**

8.5 Parameter Estimates window interpretation

As regards the parameter estimates interpretation, 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.

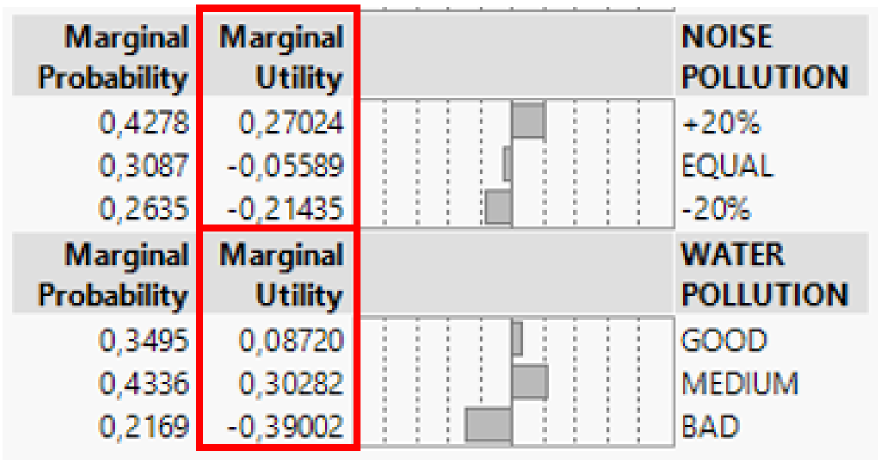
These are the β parameters that we find in the utility formula:

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

To estimate the parameter vector β we used a penalized maximum likelihood approach which maximizes the probability of obtaining the response from the selected data sample using the Firth bias correction, as explained before. 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[26] values of the attribute levels.

The marginal utility values for all but the last level of each attribute correspond to the elements of the vector β, while the marginal utility for the last level of each attribute is computed as minus the sum of all other marginal utilities for that attribute.

Thanks to this operation in the "Parameter Estimates" window there is already the starting point from which to draw for the L-R ChiSquare test.



Marginal Probability	Marginal Utility	NOISE POLLUTION
0,4278	0,27024	+20%
0,3087	-0,05589	EQUAL
0,2635	-0,21435	-20%

Marginal Probability	Marginal Utility	WATER POLLUTION
0,3495	0,08720	GOOD
0,4336	0,30282	MEDIUM
0,2169	-0,39002	BAD

[26] The marginal utility of an asset is a pivotal concept of the neoclassical theory of value in economics and can be defined as the increase in the level of utility, or the satisfaction that an individual derives from the consumption of an asset, which can be linked to marginal increases in the consumption of the good , given and constant consumption of all other goods.

Marginal utility is the amount of satisfaction that every single dose of a good consumed provides.

In non-formal terms, marginal utility can be defined as the utility provided by the last unit or consumed dose of a good. More formally, given a utility function:

$$U(x_1, x_2, \dots, x_n)$$

a function that links the consumption of given quantities of goods and services to the level of utility, the marginal utility of the good x_i is given by the partial derivative of the function with respect to x_i; in symbols:

$$U_i = \frac{\partial U(x_1, x_2, \dots, x_n)}{\partial x_i} (> 0)$$

The law of diminishing marginal utility states that as the consumption of a good increases, the marginal utility of that good diminishes.

Figure 8.6 *Effect Marginals window 1 (Source: JMP)*

Marginal Probability	Marginal Utility	COST AND CHARGES
0,0889	-0,69183	+20%
0,1649	-0,07408	+10%
0,1384	-0,24903	EQUAL
0,3770	0,75285	-10%
0,2308	0,26209	-20%

Marginal Probability	Marginal Utility	AIR POLLUTION
0,0378	-1,2921	+30%
0,0816	-0,5220	+15%
0,2036	0,3925	EQUAL
0,1480	0,0738	-15%
0,5291	1,3478	-30%

Figure 8.7 *Effect Marginals window 2 (Source: JMP)*

Marginal Probability	Marginal Utility	RESOURCE CONSUMPTION
0,0902	-0,70226	+20%
0,2428	0,28761	+10%
0,1261	-0,36723	EQUAL
0,2954	0,48374	-10%
0,2454	0,29814	-20%

Marginal Probability	Marginal Utility	PORT CAPACITY AND PRODUCTIVITY
0,6986	1,0649	+20%
0,2027	-0,1725	EQUAL
0,0987	-0,8924	-20%

Marginal Probability	Marginal Utility	PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT
0,6450	1,0137	EXTENDED
0,2853	0,1982	MEDIUM
0,0697	-1,2119	LIMITED

Figure 8.8 *Effect Marginals window 3 (Source: JMP)*

Here, above (Figure 8.6, Figure 8.7 and Figure 8.8) are reported the results about the "Effect Marginals" window, in which is also included the marginal probability[27].

As said before, the values of marginal utility are the values of the parameter estimates that are shown in the "Parameter Estimates" window.

8.6 Utility profiler window interpretation

This section simply shows the graphs of the probability function and the utility function for all the attributes and their trends based on the variation of the parameter levels.

We did a comparison among the utility of the attributes trying to change the default settings for air pollution (which is the most influent factor).

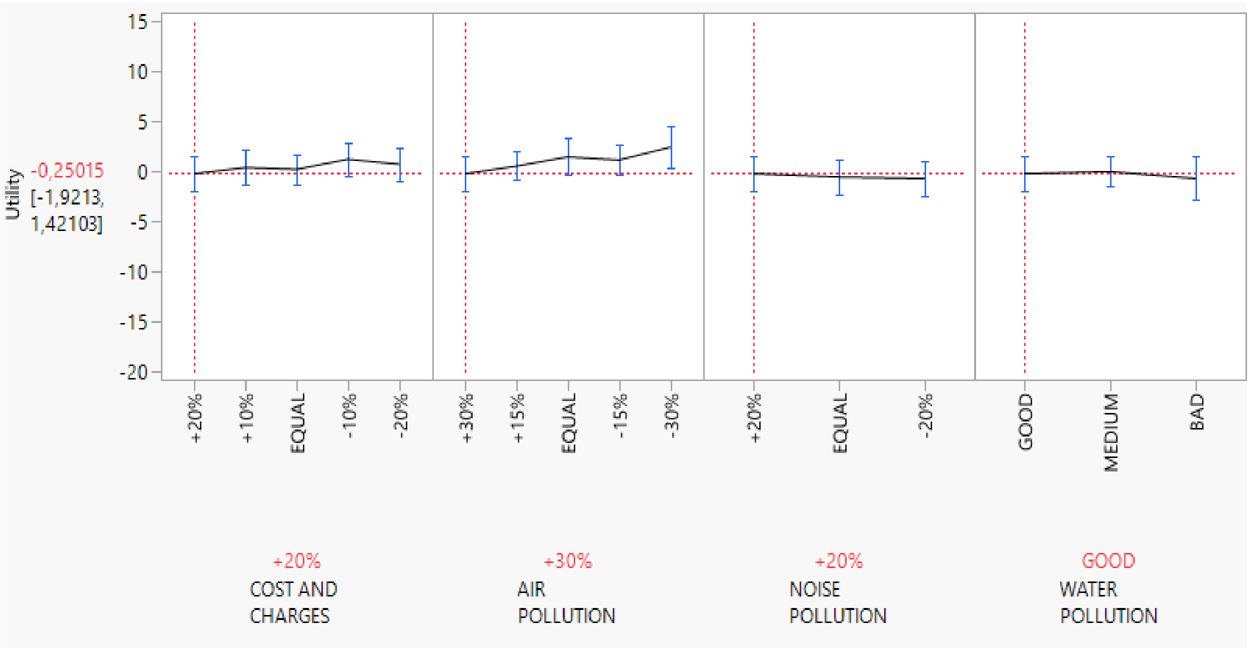


Figure 8.9 *Utility Profiler for Cost and Charges, Air, Noise, Water Pollution (Source: JMP)*

In the figure (Figure 8.9 and Figure 8.10) is possible to see with the default settings (setting levels of the attributes) which is the estimated value for the utility (-0,23015, negative), established in the confidence interval (-1,9213-1,42103)

[27] The marginal probability is the probability related to the marginal utility.

Changing the default settings and therefore changing the levels of the attribute for the air pollution (default is given the level of +30 %, we change to -30%) for example (that is the most influential factor according to our results) we could read the utility value associated to that level of influence (Figure 8.11), (we have omitted the resource consumption, port capacity and productivity and port environmental improvement and development profiles for space reasons):

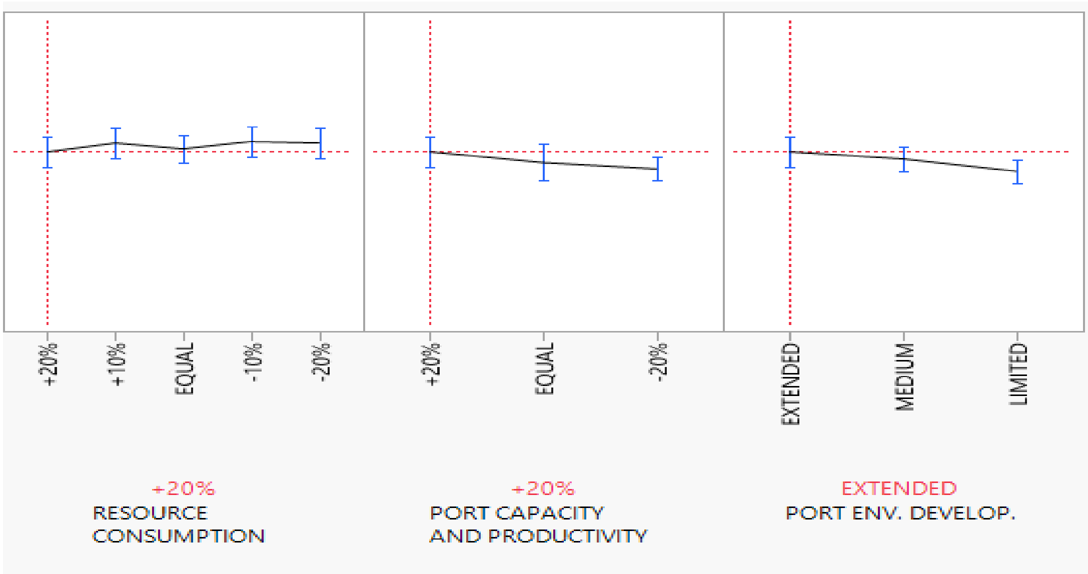


Figure 8.10 *Utility Profiler for Resource Consumption, Port Capacity and Productivity and Port Environmental Improvement and Development (Source: JMP)*

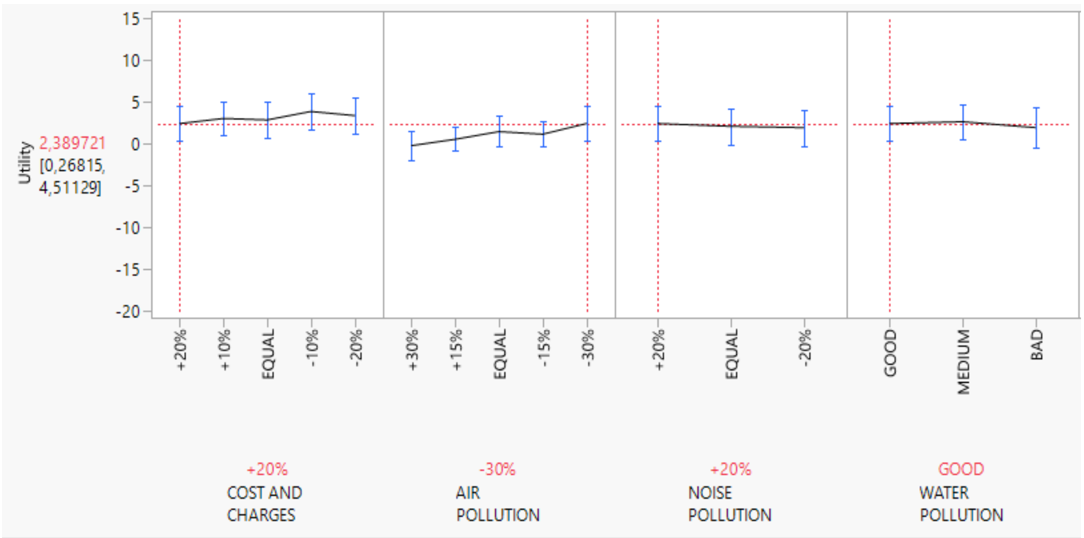


Figure 8.11 *Utility Profiler with -30% level for Air Pollution (Source: JMP)*

It is shown a value for the utility that is 2,389721 (positive) in a confidence interval between 0,26815 and 4,51129. This result could be expected for a -30% in air pollution, in fact, less air pollution can just generate better condition and it is translated in our results as a major utility value.

8.7 Likelihood Ratio Test window interpretation

In this section, we have the results of the likelihood test using a ChiSquare test application.
Leaving aside the values mentioned in the L-R ChiSquare column, to which we must only give a numerical interpretation using the theoretical formula provided for the application of the aforementioned test, what should be looked with attention is the column of degrees of freedom (DF) of the test.
In fact, these are dictated by the imposition of the null hypothesis constraint which in this case foresees setting aside, as already mentioned in the "Parameter Estimates" window the last level of each attribute. Therefore, in the test, we will have a sample of data with complete parametric space (all the complete attributes of each level) and a sample of comparison of data with limited parametric space (each attribute is deprived of the last level).
The test result leads us to see the goodness of adaptation of the competing model to the main model by evaluating the probability values in the Prob> ChiSquare column.
In the event that these values are <0.001 (assumption made previously), then the null hypothesis is rejected and therefore good adaptability is obtained. This means that in practice the two models do not differ much each other except for a possible sampling error.
If instead the assumption is not respected, then it means that the model does not have good adaptability to the suitable original one. The null hypothesis means that it is respected.
The following figure (Figure 8.12) shows the (very slight) difference between the probability values obtained in the "Effect Summary" window and those obtained in the "Likelihood Ratio Test" window (there are also reported the values in the exponential form because is easier to see the light variation):

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*

Effect Summary

Source	PValue
AIR POLLUTION	0,00000
PORT CAPACITY AND PRODUCTIVITY	0,00000
COST AND CHARGES	0,00001
PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT	0,00194
RESOURCE CONSUMPTION	0,00354
NOISE POLLUTION	0,32458
WATER POLLUTION	1,00000

Figure 8.12 *Comparison between Effect Summary and Likelihood Ratio Test window P-values (Source: JMP)*

Source	**P-value in exponential form "Effect Summary" window**	**P-value in exponential form "Likelihood Ratio Test" window**
Air pollution	18,6446e^{-8}	18,6446e^{-9}
Port capacity and productivity	592,04e^{-7}	592,04e^{-9}
Cost and charges	7,69814e^{-6}	7,69814e^{-6}
Port environmental improvement and development	1,9408e^{-3}	1,9408e^{-3}
Resource consumption	3,54445e^{-3}	3,54445e^{-3}
Noise pollution	324,584e-^{3}	324,584e^{-3}
Water pollution	1e^{0}	1e^{0}

Table 8.2 *Attribute assessment on P-values (Source: own composition according to JMP)*

Is absolutely demonstrated that the limited model used to obtain the likelihood ratio test has good adaptability respect to the original model, in fact, the P-values are the same (we didn't add further decimal places).

In the table (Table 8.2) are also shown in the values (the first three) that are accepted as "statistically significant", as we explained before (because <0,001), the value (the fourth) assumed "statistically significant", but in a borderline way (explained before).

Moreover, the values that are >0,001 (the last three). Not accepted as "statistically significant". So, the next step will be working on this group of attributes.

In Appendix D are reported the charts about the results found in this first part of the analysis, and the script code used to implement the model.

8.8 Not statistically significant *P*-values interpretation

In agreement with the table (Table 8.2) concerning the numerical value of the P-values, it is possible to conclude that there are attributes that in the Multinomial Logit Model (MNL) present statistically insignificant probability values.

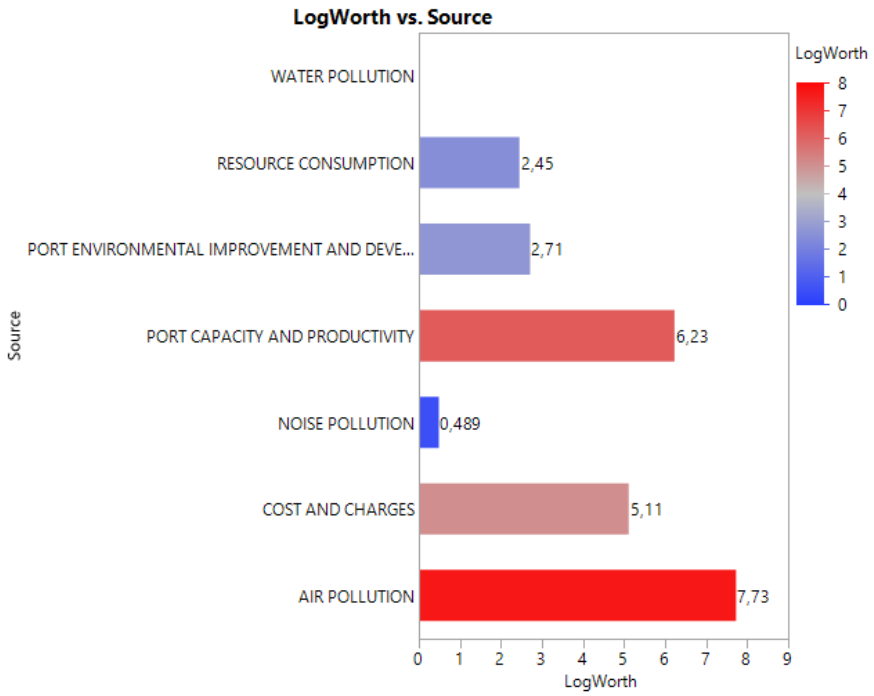


Figure 8.13 *P-values in LogWorth scale: MNL ranking attributes (Source: JMP)*

These are:

- water pollution;
- noise pollution;
- resource consumption.

This can also be explained by the figure (Figure 8.13), which establishes a ranking of the importance of these attributes according to the MNL.

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

The big problem is that between these two parameters there are water pollution and noise pollution that are among the main parameters (environmental monitoring parameters) that should characterize the concept of a green port (with great importance also of resource consumption), and instead here, in our ranking, they play a totally marginal role.

This means that shipping companies have set aside these two aspects in favour of 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).

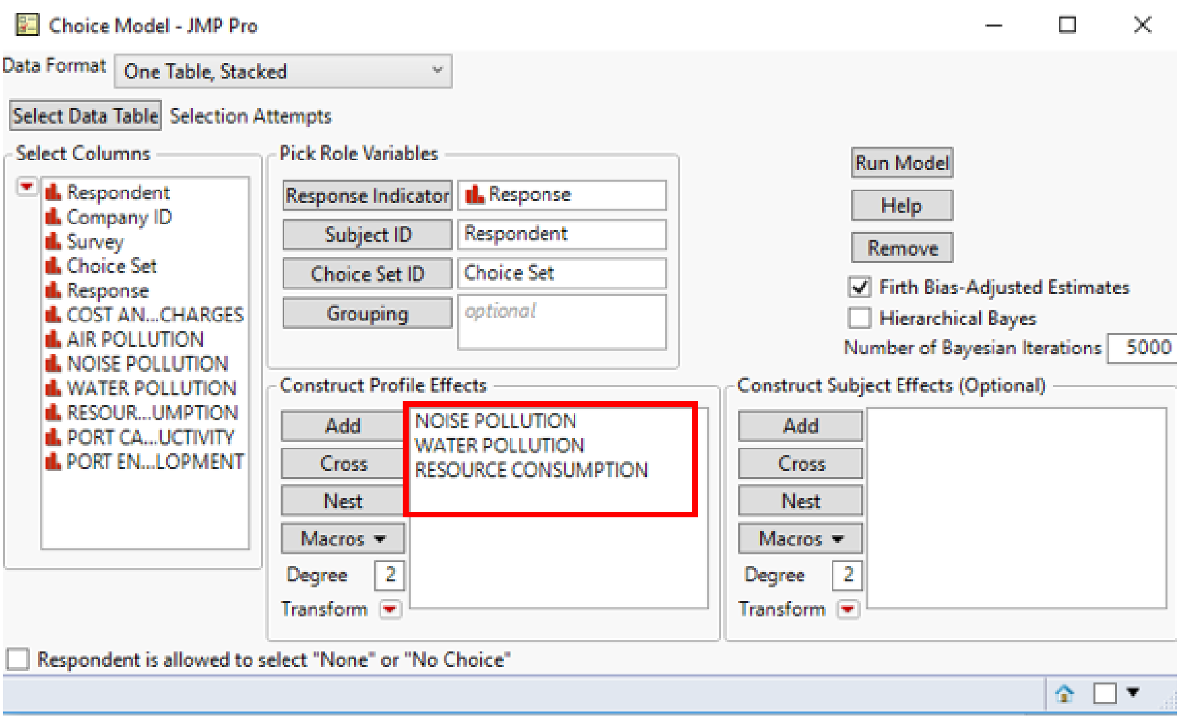


Figure 8.14 Choice Model window: Pick Role Variables chosen to run the model and attributes selection (Source: JMP)

The work we set out to do was to go and 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 7. Then again, the procedure that was performed is represented in the figure (Figure 8.14). By running the model, the following results are obtained for the "Effect Summary" window (Figure 9.15):

Effect Summary

Source	LogWorth	PValue
RESOURCE CONSUMPTION	3,262	0,00055
NOISE POLLUTION	0,135	0,73272
WATER POLLUTION	0,059	0,87385

Figure 8.15 *Effect Summary window for the three attributes (Source: JMP)*

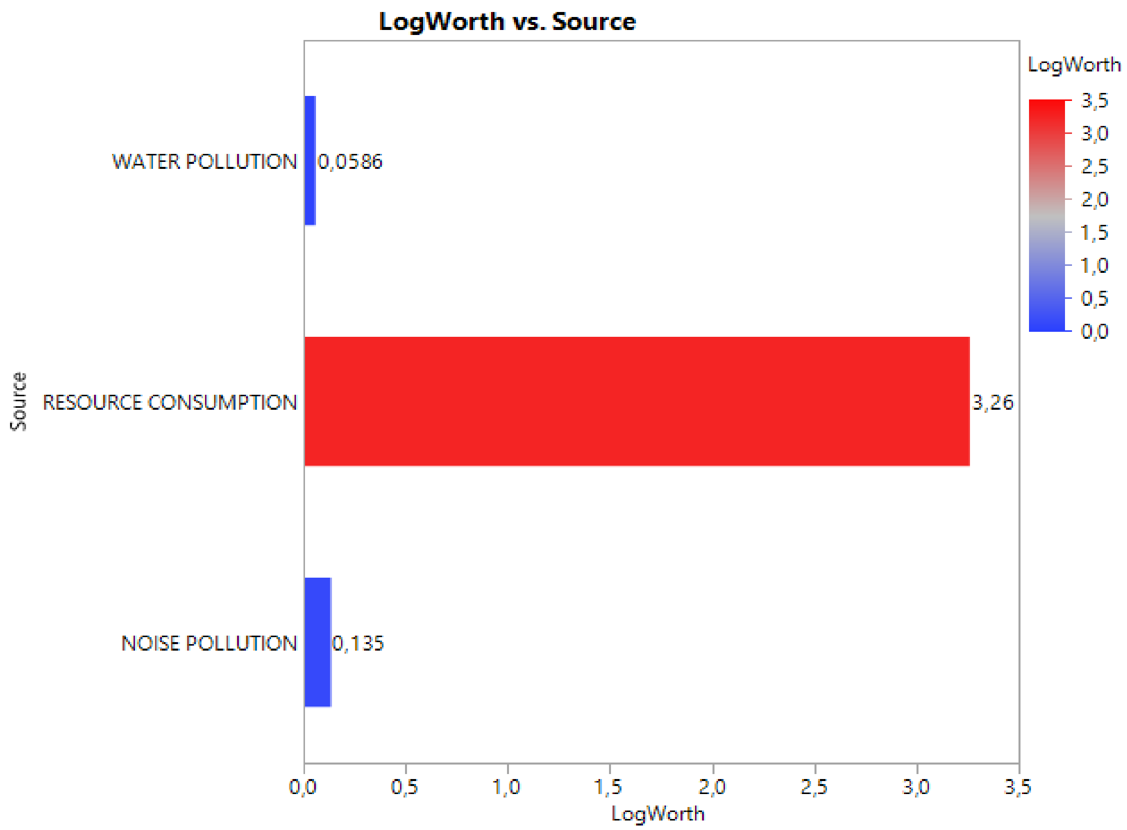


Figure 8.16 *P-values in LogWorth scale for the three attributes: MNL ranking attributes (Source: JMP)*

As can be seen from these first results, the resource consumption attribute acquires certain importance (Figure 8.16).

In fact, this attribute stands out from the other two and provides a statistically significant probability value, in fact 0.00055 < 0.001.

Nothing to do for the other two parameters that actually remain statistically not significant in their values and above all are effectively relegated to the last two positions of the established ranking. We can also observe the window of "Parameter Estimates" and the "Likelihood Ratio Test" (Figure 8.17 and Figure 8.18) and their relative graphs are shown in Appendix D.

Parameter Estimates

Term	Estimate	Std Error
NOISE POLLUTION[+20%]	0,067252393	0,1693431493
NOISE POLLUTION[EQUAL]	0,115048361	0,1690100786
WATER POLLUTION[GOOD]	0,094977154	0,1822417501
WATER POLLUTION[MEDIUM]	0,013989930	0,1841735053
RESOURCE CONSUMPTION[+20%]	-0,590971451	0,1711593853
RESOURCE CONSUMPTION[+10%]	0,306581324	0,2113910219
RESOURCE CONSUMPTION[EQUAL]	-0,290497266	0,1782431554
RESOURCE CONSUMPTION[-10%]	0,287649290	0,1842754744

AICc	383,88764
BIC	412,43459
-2*LogLikelihood	367,35627
-2*Firth LogLikelihood	339,73601

Converged in Gradient
Firth Bias-Adjusted Estimates

Figure 8.17 *Parameter Estimates window for the three attributes (Source: JMP)*

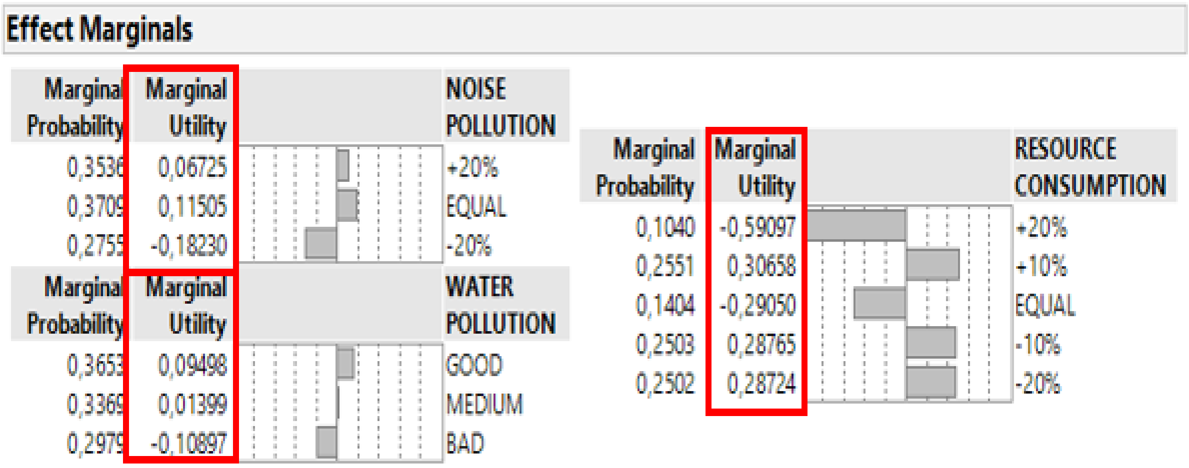
Likelihood Ratio Tests

Source	L-R ChiSquare	DF	Prob>ChiSq
NOISE POLLUTION	0,622	2	0,7327
WATER POLLUTION	0,270	2	0,8738
RESOURCE CONSUMPTION	19,798	4	0,0005*

Figure 8.18 *Likelihood Ratio Test window for the three parameters (Source: JMP)*

Here we actually see how the resource consumption attribute through the value of P-value acquires a fairly important probabilistic meaning.

Are also reported in figure below (Figure 8.19) the marginal utility values in the "Effect Marginals", as before and the relative charts are shown in the Appendix D:



Effect Marginals

Marginal Probability	Marginal Utility	NOISE POLLUTION
0,3536	0,06725	+20%
0,3709	0,11505	EQUAL
0,2755	-0,18230	-20%

Marginal Probability	Marginal Utility	WATER POLLUTION
0,3653	0,09498	GOOD
0,3369	0,01399	MEDIUM
0,2979	-0,10897	BAD

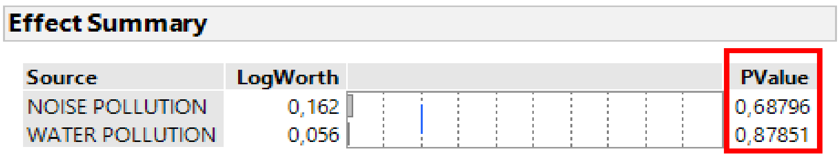
Marginal Probability	Marginal Utility	RESOURCE CONSUMPTION
0,1040	-0,59097	+20%
0,2551	0,30658	+10%
0,1404	-0,29050	EQUAL
0,2503	0,28765	-10%
0,2502	0,28724	-20%

Figure 8.19 *Effect Marginals window for the three attributes (Source: JMP)*

As we have seen, the situation studied has led to having a definitive result regarding the resource consumption attribute that stands out on water pollution and noise pollution.

It seems strange, however, but according to our analysis, it is so, that companies do not give any weight or importance to these two attributes.

A further iteration was carried out, like also done for the three attributes above, now only for water and noise pollution, but the result that emerges is that they continue to be statistically not significant. This can, in fact, be seen from the first result obtained by looking at the "Effect Summary" window in figure (Figure 8.20):



Effect Summary

Source	LogWorth	PValue
NOISE POLLUTION	0,162	0,68796
WATER POLLUTION	0,056	0,87851

Figure 8.20 *Effect Summary for Noise and Water Pollution (Source: JMP)*

As is possible to see from the "Effect Summary" window the P-values are higher than 0,001 and so they don't have any statistical significance in this case. It is unnecessary to go in depth, in this case, because we will not find anything important from this iteration.

We have to accept the condition presented, in which these two attributes cover a marginal role in our ranking.

Before to resume the whole situation, is necessary to do another consideration about noise and water pollution.

We tried to combine these two attributes with other attributes alternately in groups of three maximum four attributes, to see if they could acquire a statistical meaning.

The analysis has reported there are no cases in which the p-values of these two attributes assume a statistical significance.

So, the final situation that we consider for the continuation of our study is the one that establishes the initial ranking, show at the beginning of this paragraph and reported here again in the figure below (Figure 8.21):

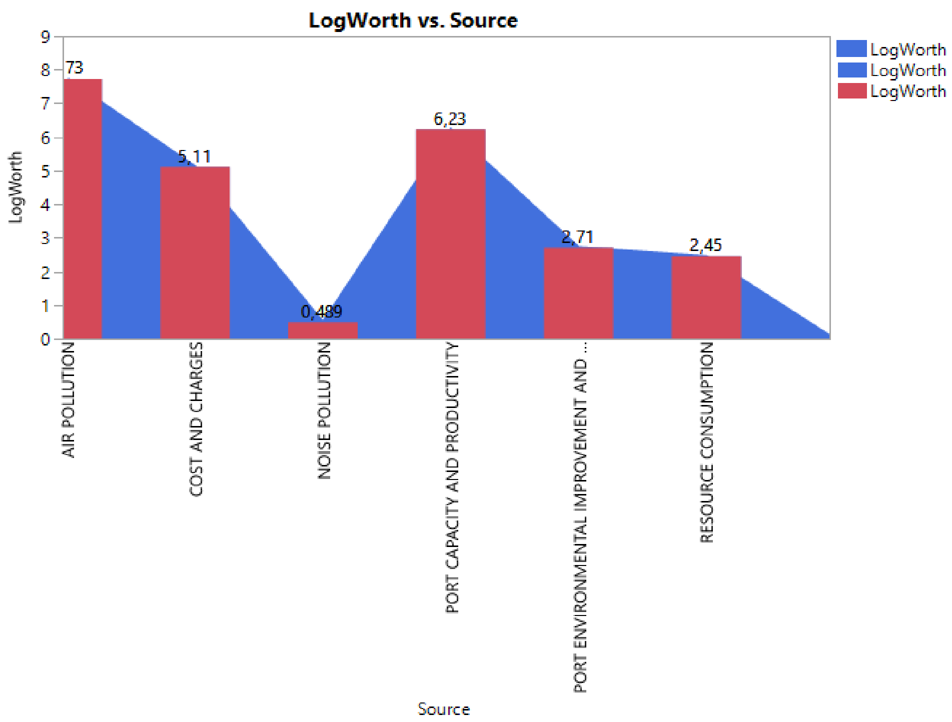


Figure 8.21 *Ranking of attributes according to P-value trend in LogWorth scale (Source: JMP)*

9 MANAGEMENT AND PREVENTION MEASURES

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 and productivity and of course the costs, and then gradually all the others.

It is reiterated again in the following image (Figure 9.1):

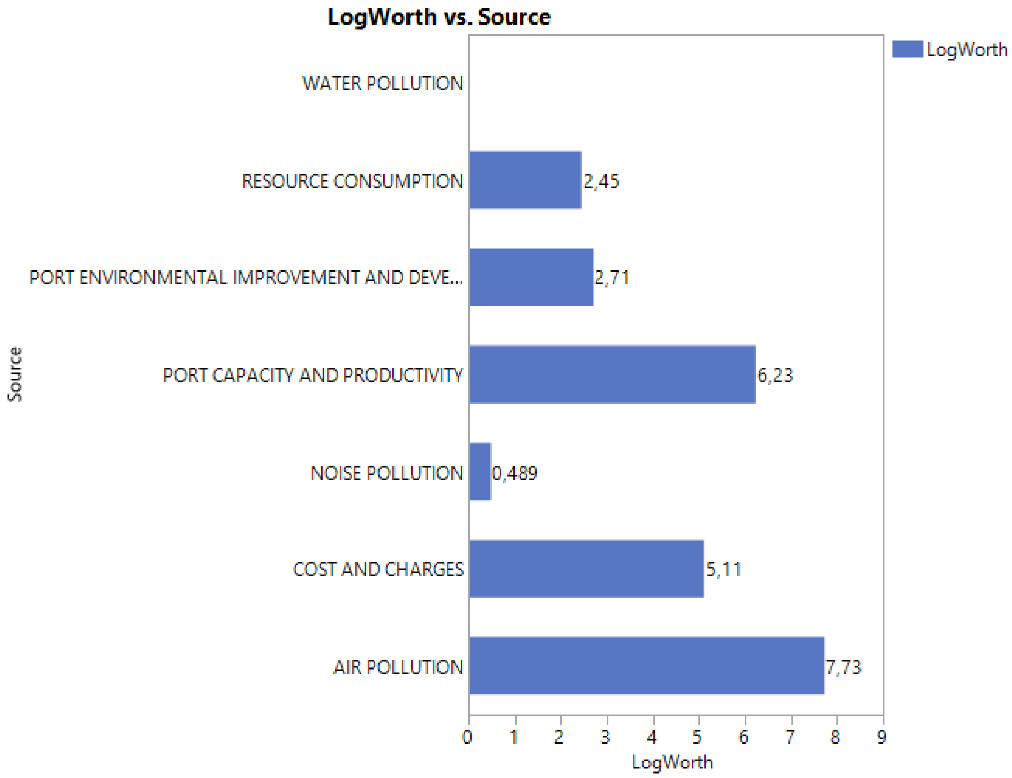


Figure 9.1 *Ranking of attributes according to P-value trend in LogWorth scale (Source: JMP)*

As already mentioned in the previous sections, in question 21 of the questionnaire the interviewed companies were asked what the preventive or management measures they would have adopted, based on their possibilities, to act on the parameters of port greening.

In this part of the research, therefore, the study of the management and preventive measures of the greening factors has been traced back to the answers provided by the companies interviewed, integrating later some considerable elements drawn from the literature, which were not mentioned by the companies.

For this reason, it was decided to divide this section into two parts.

The first part concerns the approach to these problems of port greening that the companies have provided through the answers and the second part concerns the major relevant approaches provided by a review of the literature.

This second temperature revision work has been done to give space and also to those parameters that in the established ranking have obtained less importance than the others, but that in fact deserve to be however attention and need at the same time huge and efficient preventive and management measures.

9.1 Measures proposed by interviewed shipping companies

Most companies mentioned management and prevention criteria especially by analyzing the aspects of air pollution (environmental quality) and the resource consumption in general.

To be able to give a summary scheme that collects what was described by the interviewees, it was decided to highlight the two important aspects mentioned and to add to these a further subdivision of them and therefore to report all the criteria and the management and prevention measures proposed for each element of this subdivision.

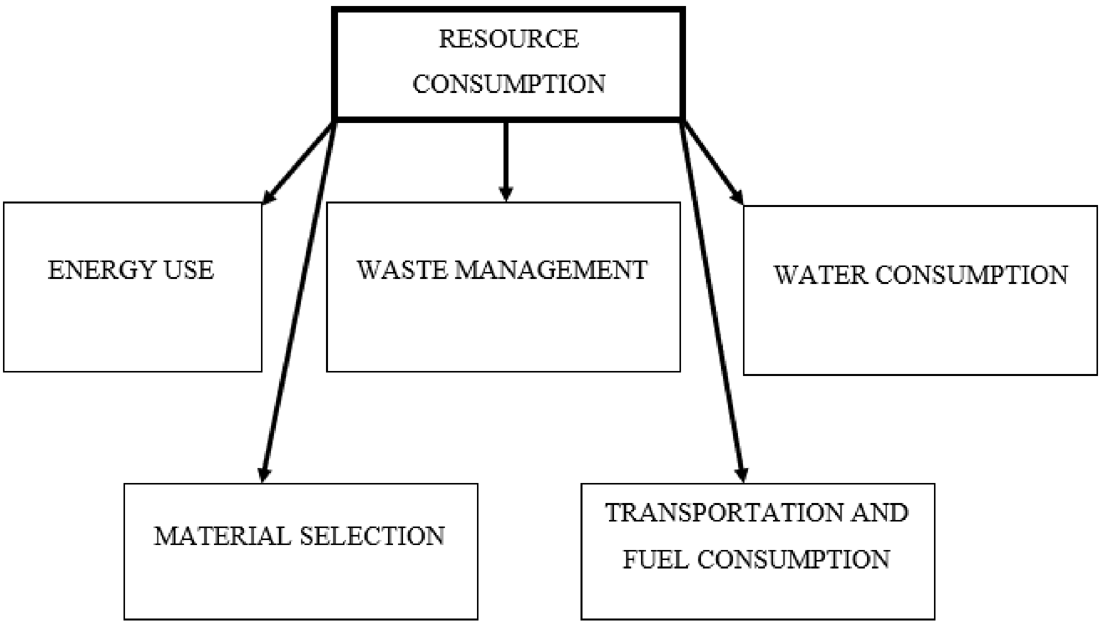


Figure 9.2 *Resource Consumption according to companies (Source: own composition)*

We have tried to build a sort of green port guidelines, starting from the chart (Figure 9.2). According to what the companies have suggested this first branch of resource consumption has been divided (from our idea) into four subcategories:

- energy use;
- waste management and material selection;
- water consumption;
- transport and fuel consumption.

For each of these four subcategories, several measures have been proposed.

Most of the companies when touching the element of waste management and material selection talk about measures like:

- minimize the generation of wastes:
    1. implementing a waste management plan, including identification of opportunities to reduce the amount of waste being disposed of at landfill;
    2. use prefabricated materials rather than those constructed on-site; use standard size for materials to avoid generating waste from offcuts;
    3. instruct contractors and suppliers to minimize packaging and select materials with less packaging;
- facilitate recycling to reduce the amount of garbage and wastes going to landfill:
    1. provide a dedicated storage area for the separation, collection and recycling of waste with good access for all building occupants and for collection by recycling companies;
    2. recycle timber, concrete, bricks, cardboard, aluminum, glass, plastic, etc.;
    3. recycle green waste;
    4. monitor quantities (volume) of waste recovery;
- ensure the safe storage and handling of hazardous goods:
    1. identify hazardous wastes and secure appropriate licenses and approvals (according to IMDG code); ensure correct handling and storage of hazardous wastes;
- reduce the number of new materials being used by reducing or reusing materials or by utilizing recycled materials:
    1. set targets to promote the reduction of materials use;
    2. reuse elements of the existing building facility where possible;

3. purchase furniture and other office/facility items that are reused or contain recycled content;
4. use recycled materials in the building/facility construction (such as recycled concrete for road base, recycled steel, …);

- Encourage environmentally friendly production of materials:
    1. use timber and composite timber products from recycled or sustainability managed sources;
    2. avoid or minimize the use of PVC plastic where possible;
- specify materials that have minimal embodied energy and environmental impact:
    1. undertake “Life Cycle Assessment” of building materials – considering the embodied energy;
    2. specify low maintenance and durable materials;

For the energy use selection, the measures proposed are:

- reduce energy consumption and hence greenhouse gas emissions:
    1. obtain a minimum predicted rating of four stars according to the emissions allowed;
    2. provide shading and insulation for the refrigerated containers; “heat stop” paint could also be used to coat the refrigerated containers;
    3. use a maintain low energy and energy efficient terminal and operational equipment and ensure equipment turns off when not required;
    4. use and maintain low energy and energy efficient appliances (such as fridges, fans, printers) and ensure appliances turn off when not required;
    5. use energy efficient light bulbs or compact fluorescent lights;
    6. maintain low power densities for lighting workspaces;
- manage the use of energy to minimize consumption:
    1. perform quality monitoring of building services performance;
    2. provide electrical sub-metering for separate energy uses such as car parks, air handling fans, lifts and common area lighting;
    3. install peak energy demand reduction systems (such as distributed energy systems or energy and thermal storage systems);
- source energy from renewable sources:

1. generate renewable energy on-site and return excess to the grid (for example solar power);
2. purchase renewable or green energy for use on-site;

- source energy from alternate energy sources and use less greenhouse intensive fuels (in particular limit diesel use):
    1. use on-site energy supply;
    2. use alternative cleaner and less greenhouse intensive fuels for cargo handling equipment, vehicles and other operational requirements (LNG, CNG, LPG);
    3. provide shore-to-ship power connections (cold ironing);

For the transportation and fuel consumption selection, the measures proposed are:

- encourage the use of alternative modes of transport by employees, in order to reduce the amount of inefficient car travel and therefore greenhouse gas emissions:
    1. limit the number of car parking spaces available;
    2. improve or provide cycle paths and or footpaths within the site and connect with existing paths also outside from the site;
    3. provide a bus link to nearby train/bus/ferry station;
    4. implement a car share plan for employees/contractors;
- reduce greenhouse gas emissions from operational vehicles and equipment:
    1. select environmentally friendly fuels and or energy efficient vehicles and equipment;
    2. coordinate trucks to avoid unnecessary truck movements and idling;
    3. investigate opportunities to maximize the transport of freight via rail;

For the water consumption selection, the measures proposed are:

- reduce the consumption of potable water used internally:
    1. ensure that the water source is suitable and that the sustainable yield has been calculated for any water extracted from the ground:
- manage and monitor water usage and any leaks:
    1. install water sub-meters for all major water uses in the building, such as cooling towers, irrigation and washdown and hot water services plus separate tenancies; monitor main and sub-meters to detect leaks;
- reduce the quantity of potable water used for landscape irrigation;

- treat water on site and reuse the treated water to reduce demand on the local potable water supply and the demand on the local infrastructure:
    1. provide a rainwater harvesting system and use rainwater to reduce consumption of potable water;
    2. provide a greywater collection treatment systems and reuse treated greywater;
    3. provide on-site blackwater treatment where appropriate and reuse a substantial proportion of treated water.

What about the environmental quality branch the topic touched from the companies have been reported in the following chart from our idea (Figure 9.3):

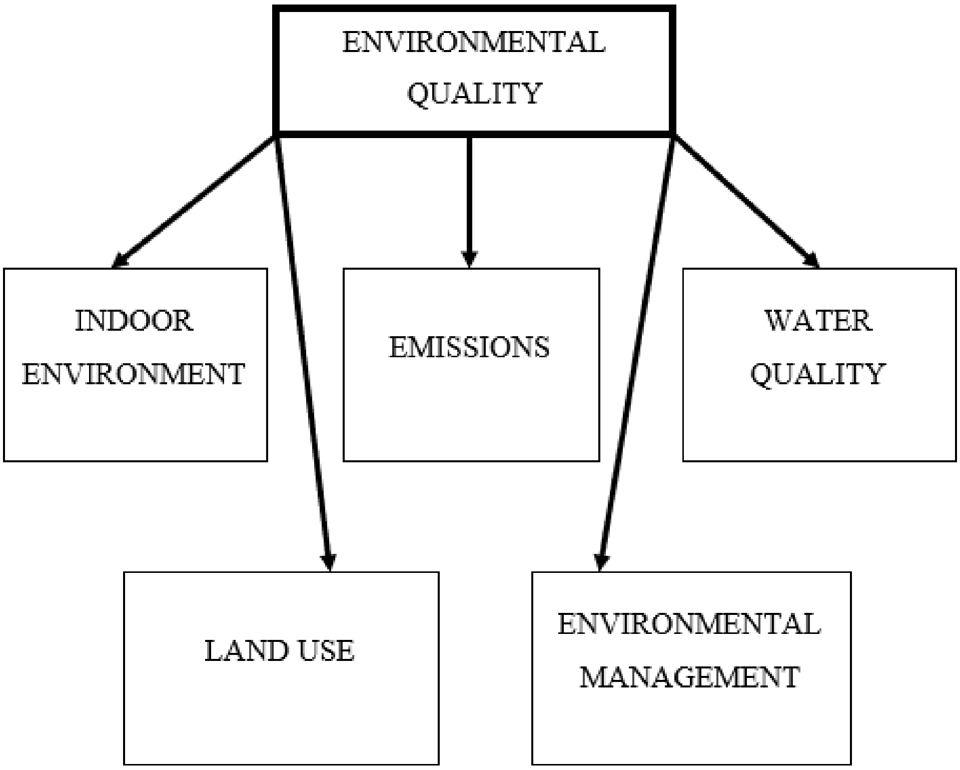


Figure 9.3 *Environmental Quality according to companies (Source: own composition)*

According to what the companies have suggested this second branch of environmental quality has been divided (from our idea) into five subcategories:

- land use;
- water quality;

- emissions;
- environmental management;
- indoor environment.

For each of these five subcategories, several measures have been proposed.

Starting from the indoor environment selection are proposed measures like:

- improve the quality of indoor air to protect the health of employees and enhance productivity:
    1. increase the outside air inflow rates in excess;
    2. use low VOC paints, low VOC carpets, low VOC sealants/adhesives;
    3. provide external exhaust for equipment rooms/areas;
    4. control humidity in workspaces and ductwork;
    5. minimize the use of cleaning and maintenance chemicals;
    6. carry out an asbestos survey and avoid the use of synthetic mineral fibers;
    7. provide separated dedicated areas with monitoring and exhaust systems for quarantine gases;

For the emissions selection are proposed measures like:

- protect the ozone layer and reduce the potential for global warming:
    1. avoid using Ozone Depleting Substances (ODS) such as refrigerants or insulants;
- limit the generation of air pollutants and ensure that they are emitted away from sensitive receptors:
    1. implement dust mitigation measures during construction and operation;
    2. consider potential sources of air pollution from operations and implement measures to control these;
- minimize odours:
    1. prevent odour pollution from construction and operations; monitor odours regularity;
- minimize noise nuisance:
    1. implement noise reduction measures for forklifts, ships, trucks, and other vehicles and machinery (such as insulation, alternative reversing alarms, back loading, on-site queuing and engine off policies);
    2. monitor noise levels during construction and operation;

- avoid light spill into night sky or neighbouring areas;
- avoid accidental contact with hazardous or poisonous goods.

For the water quality selection are proposed measures like:

- manage stormwater to reduce peak stormwater flows and protect water quality:
    1. design, provide, maintain appropriate drainage so rainwater runoff does not flow directly to surface waterbody and implement a stormwater treatment system;
- manage water quality to protect the harbour and other water bodies:
    1. identify potential sources of land-based water pollution such as truck washing, waste and cargo oil transfers and implement and maintain measures to minimize these (such as oil separators and gross pollutant traps);
    2. provide containment for any spillage including bunding and appropriate storage of liquid materials;
    3. provide emergency spill kits;
    4. implement a water quality monitoring program;
    5. manage ballast water discharge to avoid introducing non-indigenous aquatic organisms;
    6. Avoid dumping rubbish, chemicals or untreated sewage, greywater and oily bilge at sea and ensure high standard marine sanitation devices are used and maintained; avoid toxic anti-fouling paints;
- Prevent damage from potential flood events and water table changes:
    1. Assess the site for the flood risk and potential water table changes implementing appropriate mitigation measures;

For the land use selection are proposed measures like:

- encourage the redevelopment of sites that have previously been developed and remediate contaminated land;
- use landscaping to enhance biodiversity and conserve and create habitat for flora and fauna:
    1. use environmentally friendly landscape products;
    2. use nonchemical control measure for weeds and pests;
- avoid impact on identified heritage items;

For the environmental management selection are proposed measures like:

- maintain good relationships with stakeholders and respond to any complaints:
- provide a framework for identifying, managing and minimizing environmental impacts, and maximizing environmental benefits:
    1. implement a site-specific Environmental Management Plan (EMP);
    2. implement an Environmental Management System (EMS);
    3. encourage innovation in environmental management across all aspects of planning development and operations;
    4. manage environmental legislation;
- educate developers tenants and employees about ESD (Ecologically Sustainable Development) and how to improve sustainability:
    1. include a Green Star/ ESD professional design teams;
    2. provide facilities guide and training for occupants minimizing environmental impacts.

As specified from the companies all these measures forecast a lot of environmental, social and health benefits. Some of these are not so easy to implement and their use is not so likely and easy. Anyway, for each one of them there is a return on investment for the companies and also for the management companies that work in the port area (landside), that’s why they are proposed and tried to actuate.

9.2 Measures analyzed in the literature

What about this second part, in each literature document that has been reviewed, different cases of study have been faced with one unique big goal: develop a green port strategy according to several procedures to adopt in each different case.

The various documents analyzed on the different case studies report some key points in common, which in the course of our analysis we have touched very often, which form the basis for the goal of a green port. These are:

- to develop the establishment of an integrated quality management system approach to the port facility;
- to achieve improvement/prevention of seawater quality around the port facility;
- to reduce environmental pollution from ships or port operations;

- to provide maximum energy savings and to keep the highest level of energy efficiency in port operations;
- to reduce greenhouse gas and harmful emissions from the activities in boundaries of a port;
- to implement by improving renewable energy projects;
- to reduce the amount of waste originating from the operation of the port by providing waste recycling;
- to take the necessary measures and to provide permanence on occupational health and safety in port operations.

The description of these measures retrieved in literature starts introducing the following approach divided into three steps:

- step 1 - identification of instruments potentially available to port authorities to control/reduce environmental impacts of terminals;
- step 2 - identification and selection of evaluation criteria;
- step 3 - a ranking of instruments based on evaluation criteria.

The extant literature is used in steps 1 and 2 of the proposed methodology and further enriched with insights obtained from experts from academia.

9.2.1 Identification of Instruments

We begin the analysis by listing a range of tools and technologies that address broad environmental policies that governments could develop and are not specifically related to the port.

The tools are grouped into two categories (Figure 9.4):

- tools that directly limit environmental impacts;
- tools that don't.

The list of tools presented was presented by the Office of Technology Assessment (OTA) and was further refined at a later date, considering the existing literature on the management of green ports.

INSTRUMENTS THAT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS	
Setting of fixed impact reduction targets	
Single-source instruments ("command and control")	
TO needs to comply with an emission limitation or face penalties	
Harm-based standards	Description of required end results (e.g. cap on CO2 emission of terminal)
Design standards	Description of required emission limits based on model technology
Technology specifications	Specification of the technology the TO must use to control its pollution
Bans and limitations	Ban or restrict equipment or operations that present unreasonable risks
Multi-source instruments (limits on cumulative impacts from multiple sources)	
TO has some flexibility in how it complies with specific environmental targets => change own behavior or make other entities comply on the TO's behalf	
Integrated permitting	Multiple requirements into a single permit
Tradeable emissions	Allow TOs to trade emission control repsonsibilities among themselves given an aggregate regulatory cap on emissions
Challenge regulations	TOs are given responsibility for designing and implementing a program to achieve imposed target.
INSTRUMENTS THAT DO NOT DIRECTLY LIMIT ENVIRONMENTAL IMPACTS	
Encouragement of pollution control without setting specific emission targets	
Pollution charges	TO pays fixed amount for each unit of pollution (no ceiling)
Liability	TO pays compensation to those that are harmed by impacts
Information reporting	TO needs to report impacts publicly
Subsidies/discounts	Financial assistance or discounts to TOs as an incentive/carrot to change their behavior, or to help defray costs of mandatory standards.
Technical assistance	Knowledge support to TOs (good practice guide, training, information centre)

Figure 9.4 *Categories of instruments (Source: The greening of terminal concessions in seaports)*

9.2.2 Identification and Selection of Evaluation Criteria

In a second phase, the criteria that can be used to assess whether a specific instrument is relevant in a terminal concession context are identified and selected.

A list of criteria has been drawn up thanks many studies and researches and above all thanks to the support of international organizations and environmental congresses that have worked for this purpose.

9.2.3 Evaluation criteria and following ranking of instruments

There are four important evaluation criteria that have to be considered to evaluate if an instrument is suitable or not, if it works or it can’t work.

These are:

- legal certainty of the instrument;
- regulatory jurisdiction;
- level playing field (equity of the tool for the maritime operators involved);
- regulatory costs (for governments, Port Authorities and maritime operators).

9.3 Technical measures and operational measures

From a pure transport economics perspective, the optimization of pollution is not its minimization. Exists an optimal level of environmental improvement beyond which the marginal costs of further emission reductions exceed the marginal benefits

Regulation costs are part of these marginal costs and typically include personnel costs and investment in and maintenance of capital/technical equipment needed to implement and enforce the regulation.

Because of the close link between fuel consumption and the volume of emissions from shipping, the most obvious method of reducing emissions is to reduce fuel consumption, which in turn reduces costs.

This is the so-called ‘green-gold’ paradigm.

In seeking to unilaterally reduce their fuel consumption and costs therefore, a variety of technical and operational measures are available to the operators of ships.

9.3.1 Technical Measures

Technical measures for reducing fuel consumption result in the production of fewer harmful emissions per unit of output or work. Such measures include the following:

Greater engine efficiency

Over the past thirty years, marine engines have been developed which are more efficient, with lower Specific Fuel Oil Consumption (SFOC).

For instance, attempts have been made to optimize the combustion process by raising the ratio of the maximum (firing) pressure and the mean effective pressure and by deploying electronic engine control systems with more parameters for adjustment compared to a standard camshaft (or mechanical) control system.

Waste heat recovery

The exhaust gas and cooling water from ships contain substantial energy that could be harnessed, thereby improving the overall thermal efficiency of the engine system by about 5–10%.

Maersk Line was the first shipping company to install waste heat recovery systems as standard on all its new ships. Their system works by utilizing the very high heat potential contained in the exhaust gas leaving the engine; it is converted to steam in an exhaust gas boiler, which is then supplied to a turbine connected to a generator which then recovers electrical energy.

In this way, the engine's waste heat is changed into valuable electric power, thus reducing the fuel consumption of the ship, as well as the associated CO_2 and other atmospheric emissions.

At an installation cost of $10 million per ship, this represents a payback period of somewhere in the range 5–10 years depending on fuel price and service speed.

Improved hull design and performance

To facilitate propulsion, it is necessary to either reduce the weight of a ship by selecting appropriate lighter design materials which do not compromise hull strength or to reduce the resistance of the ship in the water. The shape and form of the hull clearly play an important role in minimizing resistive forces, but there are other less obvious considerations. For example, both animals (e.g. barnacles, molluscs, polychaete worms, encrusting hydroids and sea squirts) and plants (e.g. green, red and brown algae and diatoms) can live on the hull of a ship.

Such fouling communities can significantly increase the frictional resistance of a ship, leading to greater fuel consumption and associated exhaust emissions.

As a consequence, a whole international industry has evolved around the development of anti-fouling paints and coatings that minimize hull fouling. Compared to an untreated hull, effective antifouling paint can reduce fuel consumption by at least 15% due to reduced drag.

However, although these anti-fouling paints and coatings have additional environmental benefits in that they reduce the likelihood of transporting invasive marine species, they have created their own environmental problems through their previous reliance on tributyltin (TBT), which itself is known for its highly toxic and endocrine disrupting properties. Although the

IMO banned TBT from use in anti-fouling paints, full compliance remains a long way from being attained.

<u>More efficient propellers and rudders</u>

In general, the larger the propeller diameter, the higher the propeller efficiency and the lower the optimum propeller speed. Thus, achieving a propeller speed which is as low as possible (within the design restrictions of a ship) is the desired objective.

When the design speed of a ship is reduced, the corresponding propulsion power and propeller speed will also be reduced, which again may have an influence on the propeller and main engine parameters, aspects which are very germane to the operational strategy of 'slow steaming,'

9.3.2 Operational Measures

Because of the strength of the link between fuel usage and emissions to air, any measure which improves operational efficiency should also result in less environmental damage. Some of the approaches adopted for improving the operational efficiency of shipping include the following:

<u>Reduction in vessel speed.</u>

Reducing ship speed reduces fuel consumption and therefore, CO_2 and other atmospheric emissions.

From some studies conducted by Maersk, it has been reported that reducing speeds by 20% leads to fuel consumption savings of 40% and CO_2 emission reductions of about 7%.

In practice, speeds can be reduced from an average range of about 23–25 knots down to slow steaming speeds of 20–22 knots, or even extra slow steaming at 17–19 knots.

However, particularly in the container industry, slower speeds have implications for delivery times and the competitiveness of shipping versus other modes. Depending upon the nature of specific routes and the efficiency of ports on those routes, slow steaming can lengthen round-trip times by 10–20%.

Ultimately, the systematic adoption of slow steaming would, ceteris paribus, reduce shipping supply to the market. This would result either in higher shipping prices or, more likely, more ships having to be built. More ships in the fleet means more energy being used in the production process as well as more emissions from the additional vessels. Also, additional crews will have to be recruited to an industry where finding suitable human resources is very difficult. Additionally, operating a ship at a speed lower than its design speed could lead to higher maintenance costs and longer downtime.

Improved routing and scheduling

Operational efficiency can be improved by considering the weather in the routing of ships. Also, scheduling in order to minimize the amount of idle time spent waiting in port to either load or discharge cargoes is also important (in these phases there are also emissions and dispersion of PM).

9.4 The Regulatory Regime

The IMO has a long history of regulating ship pollution through its International Convention on the Prevention of Pollution from Ships (known as the MARPOL Convention). However, little attention was paid to atmospheric emissions until the 1980s. The MARPOL Convention was updated by the '1997 Protocol' to include an Annex VI entitled 'Regulations for the Prevention of Air Pollution from Ships'.

This annex prohibits the deliberate emission of ozone-depleting substances in line with the Montreal Protocol and sets limits on the emissions of NO_x and SO_x from ship exhausts.

SO_x regulations

The latest revised version of MARPOL Annex VI sets the following global limits on the sulfur content of a ship's fuel: A reduction to 3.50% (35,000 ppm), effective 1 January 2012.

A reduction to 0.50% (5,000 ppm), will be effective 1 January 2020 but subject to a review to be completed no later than 2019. If this review will be negative, the effective date defaults to 1 January 2025.

NO_x regulations

Nitrogen Oxides (NO_x), specifically, are formed during combustion. The IMO NO_x emission standards are based on an engine's maximum operating speed (in rpm) since generally the lower the rpm, the greater the NO_x. The limits are expressed in g/kWh.

Standards are expected to be met by designing the engine to optimize the combustion process through the regulation of fuel injection (rate shaping) such that timing, pressure and rate, fuel nozzle flow area, exhaust valve timing and cylinder compression volume are all jointly optimized.

Greenhouse Gas (GHG) regulations and guidelines

The IMO has adopted a dual approach to reducing the greenhouse gases of the shipping industry. First, it is devising a range of 'Technical and Management Strategies' which will either improve the fuel efficiency of the sector or reduce greenhouse gas emissions in some other way.

The IMO's Energy Efficiency Design Index (EEDI), in force since January 2019, is a formula that is intended to enable ship designers and builders to design and construct ships of the future for maximum fuel efficiency and, thus, minimum greenhouse gas emissions.

Have been highlights three potential policy instruments that could be used by the EU (and could be extended in all the world) and which would appear to be quite similar to those already under consideration at the IMO:

- a cap-and-trade system for maritime transport emissions;
- an emissions tax with hypothecated revenues;
- a mandatory efficiency limit for ships in EU ports (possibility to extend in all ports in the world).

9.5 Routes to compliance: Alternative Sources of Energy

The use of alternative sources of energy has the potential to reduce a specific individual form of emission from ships, a number of emissions simultaneously and/ or to enhance fuel efficiency. There exist a number of alternative energy options for ships which have proven technical viability. However, each of the alternatives analyzed below does exhibit its own inherent advantages and disadvantages.

Low Sulphur Fuels (LSF)

These reduce sulfur emissions directly whilst also indirectly decreasing PM and CO_2 emissions. However, in order to produce sufficient quantities of low sulfur fuel, the residual oil which is currently used as marine fuel will need to be further processed. In addition, the sort of caps which will apply within ECAs (Emission Control Area) simply cannot be attained through the use of standard low sulfur bunker fuel. Thus, in order to comply with increasingly stringent ECA regulations, standard low sulfur fuel will have to be utilized in tandem with some form of abatement technology.

Biofuels

Biofuels works well in ship engines. It can provide 100% of a ship's fuel or it can be blended with conventional fuel. For example, a 5% biodiesel content in the fuel results in a CO_2 reduction of about 4%.

Additionally, biofuels do not contain sulfur.

Hydrogen

The main form of hydrogen to be used in transport is the hydrogen fuel cell. This is a device which converts hydrogen gas and oxygen into water via a process which generates electricity.

The main environmental benefit of hydrogen is that its only real emission is water vapour. As more research into the use of hydrogen is carried out, however, major doubts have crept in concerning its environmental credentials.

Hydrogen is an energy carrier, not an energy source. This means that it must be produced from other sources (coal, nuclear, etc.).

(Its polluting emissions have been questioned. Hydrogen is an indirect greenhouse gas with a potential global warming effect.

In order to produce hydrogen fuel cells, a small amount of platinum (which acts as a catalyst) is required and there are significant negative environmental effects associated with the extraction and refining of platinum.

The practical deployment of hydrogen as a fuel within maritime transport is currently minimal and limited exclusively to highly specialized vessels.

Research is underway on various fuel cell technologies, in particular, the use of LNG for use with fuel cells and, ultimately, the possibility for ships to create their own hydrogen from seawater on which traveling.

Wind and solar energy

Several shipping companies have experimented with wind and solar energy.

The ECSA (European Community Shipowners' Association) and ICS (International Chamber of Shipping) suggest that both solar and wind power could become important supplementary sources of energy but that they are unlikely to ever be more than this.

Liquid Natural Gas (LNG)

Using LNG as a fuel for ships is undoubtedly one of the best available options in terms of environmental performance, as it emits only small amounts of NO_x, SO_x and PM. In addition, the use of LNG will also yield quite a significant reduction in CO_2 emissions. There are very large reserves of LNG, so it is regarded as a fuel of the future. In addition, LNG remains a relatively cheap fuel alternative.

However, despite the benefits in terms of fuel cost and the environment, there are several practical difficulties that need to be overcome in utilizing LNG as a fuel for ships. These include various technical storage and logistical issues relating to:

- the space requirements for natural gas, both ashore and onboard;
- the specialized nature of the technology required for handling LNG and;
- the limited number of currently available locations for supplying ships with LNG.

In summary, therefore, current technologies suggest that the immediate use of LNG as a marine fuel will be limited to auxiliary engines and main engines when used on shorter voyages.

9.6 Routes to compliance: Abatement Technology

An alternative, or possibly supplementary, approach to the use of different sources of energy is the deployment of abatement technology in order to comply with emissions regulations. In this respect, there is a range of commercially available systems and products. Here have been described some of them.

Selective Catalytic Reduction (SCR)

The SCR system is a commercial product that reduces NO_x. It is a catalytic exhaust treatment with an additional oxidation option to lower volatile organic compounds (VOCs) and carbon monoxide (CO).

Urea is injected into the hot exhaust gas and reacts with the NO_x content to produce harmless nitrogen (N_2) and water. The system requires space for deployment within the engine room, but the reduction rate of NO_x achieved is somewhere around 90–95%.

Humid Air Motor (HAM)

A HAM system yields a 70–80% reduction in NO_x by introducing approximately three times as much water vapour as fuel into the engine.

Since the system uses evaporated seawater to reduce the temperature in the cylinder, running the HAM system incurs only very minimal additional operating costs. The way the system works is that by humidifying the hot charge air from the compressor in a water spray chamber, the heat capacity of the charge air is increased. This means that it can absorb more heat. At the same time, the oxygen content of the charge air is reduced. This process results in a lower combustion temperature in the engine and, in consequence, reduced NO_x emissions; as the formation of NO_x content in exhaust gas is positively correlated to combustion temperature.

Shore-Based Power (‘Cold Ironing’)

Cold ironing is the use of shore-based power to provide electrical energy to a ship while at berth rather than using its auxiliary engines. This means that all engines can be shut down.

The practice is one of the most important elements in the definition of the green port concept.

The large-scale deployment of cold ironing could significantly reduce the remaining number of poor air quality hotspots, as well as substantially reducing noise. The major barriers to the widespread take-up of cold ironing, however, are the high costs of the installation or retrofitting of appropriate power systems on ships and the expansion of electricity lines, substations, etc. onshore, both in port and beyond.

10 CONCLUSIONS

In this research, a very sensitive topic has been addressed and nowadays of great importance in the transport sector.

All the results obtained from this study have highlighted some very significant aspects of the subject. Maritime transport, as has been observed, has various effects on the environment and the mitigation measures for these effects are of considerable importance.

These mitigation measures, addressed in the penultimate chapter, can be further summarized in five final 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 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 as

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. Many times, in fact, the regulatory measures are not sufficient and therefore also technologically intervened.

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 such as ESPO in order to facilitate the formation of a sustainable and green maritime industry as much as possible.

Rewarding ports, ships, companies for their best performance is considered a refined and very effective means of giving space to sustainable navigation.

Finally, the awareness that the maritime industry and all the subjects involved in it must have to face the environmental effects, and to be able to give ample space and safe application to the measures described up to now, must be an essential attribute. From this comes the effectiveness of the solutions in dealing with the problems and the consistency of the measures adopted.

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 key elements of the economic growth of some world powers. First of all, China.

The attention that is given to the establishment of ports as ecological as possible becomes a parameter of economic development of fundamental importance.

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 our case, but in general in all other cases) we tend above all to rationalize the use of environmental resources and consequently a lower expenditure of economic resources will be obtained in the long term, with social and political benefits.

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? and 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?

These questions are for us the basis of future studies and future research on this topic.

We are going to close this work, leaving with two pictures, taken in the Port of Antwerp (Figure 10.1 and Figure 10.2) during a visit to one of the companies which cooperated.

Figure 10.1 *Container ship in Port of Antwerp (Source: own source)*

Figure 10.2 *Aerial view of the Port of Antwerp in the evening (Source: own source)*

11 REFERENCES

CHEN, J., HUANG, T., XIE, X., TAE-WOO-LEE, P., HUA, C., 2019., (March). *Constructing governance framework of a green and smart Port*. Journal of Marine Science and Engineering, Vol. 7, No. 83, 1-17

WALKER, T.R., ADEBAMBO, O., HOSSAIN, M.T., JOHNSTON EDWARDS, S.C., 2019., (March). *Chapter 27: Environmental effects of marine transportation*. World Seas: an Environmental Evaluation (Second Edition), Vol. 3: Ecological Issues and Environmental Impacts, 505-530

JMP STATISTICAL DISCOVERY FROM SAS., VERSION 14., 2018. *JMP 14 Basic Analysis*. SAS Institute Inc. 2018, Online source: https://support.sas.com/documentation/onlinedoc/jmp/14.0/Basic-Analysis.pdf

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (UNCTAD)., Geneva., 2018. *Review of maritime transport 2018: reflecting on the past, exploring the future*. Transport and Trade Facilitation, Series No. 10, Online source: https://unctad.org/en/PublicationsLibrary/rmt2018_en.pdf

DI VAIO, A., VARRIALE, L., ALVINO, F., 2018., (November). *Key performance indicators for developing environmentally sustainable and energy efficient ports: evidence from Italy*. Energy Policy, Vol. 122, 229-240

ACCIARO, M., FERRARI, C., LAM, J., MARCARIO, R., ROUMBOUTSOS, A., SYS, C., VANELSLANDER, T., TEI, A., 2018., (April). *Are the innovation processes in seaport terminal operations successful?*. Maritime Policy and Management, Vol. 45, No. 6, 787-802

HOSSAIN, T., 2018., (June). *Assessment of sustainability initiatives in port operations: an overview of global and Canadian ports*. Dalhousie University Halifax, Nova Scotia, Online source: https://pdfs.semanticscholar.org/1f99/f176b73df594e79c7505c365db24883ae128.pdf

CUI, H., NOTTEBOOM, T., 2018., (April). *A game theoretical approach to the effects of ports objective orientation and service differentiation on port authorities willingness to cooperate*. Research in Transportation Business and Management, Vol. 26, 76-86

MUNIM, Z.H., SAEED, N., LARSE, O.I. 2018., (May). *"Tool Port" to" Landlord Port": a game theory approach to analyze gains from governance model transformation*. Maritime Policy and Management, Vol. 46, No. 1, 43-60

EUROPEAN SEA PORTS ORGANIZATION (ESPO)., 2018. *ESPO ENVIRONMENTAL REPORT 2018: EcoPortsinSights 2018*., (17 November). Online source: https://www.espo.be/publications/environmental-report-2018

MARZANTOWICZ, L., DEMBINSKA, I., 2018., (July). *The reasons for the implementation of the concept of green port in sea ports of China*. Logistics Infrastructure 2018, 121-128

NOTTEBOOM, T., SIU LEE LAM, J., 2018., (September). *The greening of terminal concessions in seaports*. Sustainability 2018, Vol. 10, No. 9, 1-17

PUIG, M., PLA, A., DARBRA, R.M., 2017., (May). *Tool for the identification and implementation of Environmental Indicators in Ports (TEIP)*. Ocean and Costal Management, Vol. 140, 34-45

ARONIETIS, R., SYS, C., VAN HASSEL, E., VANELSLANDER, T., 2017., (December). *Investigating the bunkering choice determinants: the case of the Port of Antwerp*. Journal of Shipping and Trade (2017), Vol. 2, No. 8, 1-13

WALKER, T.R., 2016., (April). *Green marine: an environmental program to establish sustainability in marine transportation*. Marine Pollution Bulletin, Vol. 105, No. 1, 199-207

FAHIMNIA, B., DAVARZANI, H., SAKARIS, J., BELL, M., 2016., (July). *Greening ports and maritime logistics: a review and network analysis*. Transportation Research Part D: Transport and Environment, Vol. 48, 473-487

VANELSLANDER, T., 2016., (June). *Seaport CSR: innovation for economic, social and environmental objectives*. Social Responsibility Journal, Vol. 12, No. 2, 382-396

VANELSLANDER, T., NAZEMZADEH, G.M., 2015., (June). *The container transport system: selection criteria and business attractiveness for North-European ports*. Maritime Economics and Logistics, Vol. 17, No. 2, 221-245

WEN, W., SUN, Y., ZHANG, E., 2015., (January). *Analysis on low-carbon and green container port- building goal systems*. Transportation Management College, Dalian Maritime University in China., published on Atlantis Press. Online source: https://www.researchgate.net/publication/301406427_Analysis_on_Lowcarbon_a_Green_Container_Port-building_Goal_System

MANSOURI, S.A., LEE, H., ALUKO, O., 2015., (June). *Multi-objective decision support to enhance environmental sustainability in maritime shipping: a review and future directions*. Transport Research Part e: Logistic and Transportation Review, Vol. 78, 3-18

PUIG, M., WOOLDRIDGE, W., DARBRA, R.M., 2014., (April). *Identification and selection of Environmental Performance Indicators for sustainable port development*. Marine Pollution Bulletin, Vol. 81, No. 1, 124-130

BERGMANS, A., LOOTS, I., VANDERMOERE, F., 2014., (July). *Co-producing sustainability indicators for the port of Antwerp: how sustainability reporting creates new discursive spaces for concern and mobilisation*. Journal for Communication Studies, Vol. 7, No. 1, 107-123

HER CHIU, R., HUI LIN, L., CHAN TING, S., 2014., (January). *Evaluation of Green Port Factors and Performance: a Fuzzy AHP Analysis*. Hindawi Publishing Corporation, Mathematical Problems in Engineering, Vol. 2014, 1-12

ACCIARO, M., VANELSLANDER, T., SYS, C., FERRARI, C., ROUMBOUTSOS, A., GIULIANO, G., SIU LEE LAM, J., KAPROS, S., 2014., (August). *Environmental sustainability in seaports: a framework for successful innovation*. Maritime Policy and Management, Vol. 41, No. 5, 480-500

SIU LEE LAM, J., NOTTEBOOM, T., 2014., (February). *The greening of ports: a comparison of port management tools used by leading ports in Asia and Europe*. Transport Reviews, Vol. 34, No. 2, 169-189

EUROPEAN ENVIORNMENTAL AGENCY (EEA), 2013. *The impact of the international shipping on European air quality and climate forcing*. EEA Technical Report, No. 4/2013, 1-84, Online source: https://www.eea.europa.eu/publications/the-impact-of-international-shipping/file

CULLINANE, K., CULLINANE, S., 2013., (June). *Atmospheric emissions from shipping: the need for regulation and approaches to compliance*. Transport Reviews, Vol. 33, No. 4, 377-401

VANELSLANDER, T., SYS, C., ACCIARO, M., GIULIANO, G., ROUMBOUTSOS, A., RASHED, Y., MACARIO, R., LAM, J., KAPROS, S., FERRARI, C., 2013., (October). *Port innovation: definition and typology*. Department of Transport and Regional Economics at Faculty of Applied Economics at University of Antwerp. Universiteit Antwerpen, 1-15

VANELSLANDER, T., SYS, C., ACCIARO, M., GIULIANO, G., ROUMBOUTSOS, A., 2013., (October). *Port innovation: methodology approach*. Department of Transport and Regional Economics at Faculty of Applied Economics at University of Antwerp. Universiteit Antwerpen, 1-30

CHANG, Y.T., 2013., (May). *Environmental efficiency of ports: a data envelopment analysis approach*. Maritime Policy and Management, Vol. 40, No. 5, 467-478

MUSSO, A., PICCIONI, C., VAN DE VOORDE. E., 2013., (January). *Italian seaports' competition policies: facts and figures*. Transport Policy, Vol. 25, 198-209

DOCENTI UNINA, 2013., (September). Disponibilità a pagare e Il Discrete Choice Experiment, Online source: https://unctad.org/en/PublicationsLibrary/tdbc4d110rev1_en.pdf

LIRN, T.C., WU, Y.C.J., CHEN, Y.J., 2013., (June). *Green performance criteria for sustainable ports in Asia*. International Journal of Physical Distribution and Logistics Management, Vol. 43, No. 5/6, 427-451

KUPFER, F., 2012., (June). *The Airport choice for scheduled freighter operations in Europe*. Ph.D. Thesis for Department of Transport and Regional Economics at Faculty of Applied Economics at University of Antwerp. Universiteit Antwerpen, 1-176

CHANG, C.C., WANG, C.M., 2012., (May). *Evaluating the effects of green port policy: case study of Kaohsiung harbour in Taiwan*. Transportation Research Part D: Transport and Environment Vol. 17, No. 3, 185-189

KESSELS, R., JONES, B., GOOS, P., 2011., (March). *Bayesian optimal design for discrete choice experiments with partial profiles*. Journal of Choice Modelling, Vol. 4, No. 3, 52-74

ACOSTA, M., CORONADO, D., DEL MAR CERBAN, M., 2011., (July). *Bunkering competition and competitiveness at the Ports of the Gibraltar Strait*. Journals of Transport Geography 19, 911-916

YING, H., YIJUN, J., 2011., (January). *Discussion on green port construction of Tianjin Port*. International Conference on Biology, Environment and Chemistry., IPCBEE Vol. 1 (2011)., published on IACSIT Press. Online source: http://www.ipcbee.com/vol1/108-Z00419.pdf

CHOU, C.C., 2010., (April). *AHP model for the container port choice in the multiple ports region*. Journal of Marine Science and Technology, Vol. 18, No.2, 221-232

KANAFANI, A., MALCHOW, M., 2010., (December). *A disaggregate analysis of factors influencing port selection*. Maritime Policy and Management, Vol. 28, No. 3, 265-277

QUYNH, L.X., HENS, L., STOYANOV, S., 2010., (May). *Water management in the framework of environmental management systems in Bulgarian seaports*. Physics and Chemistry of the Earth, Vol. 36, No. 5-6, 141-149

NG. A.K.Y., SONG, SU., 2010., (June). *The environmental impacts of pollutants generated by routine shipping operations on ports*. Ocean and Costal Management Vol.53, No. 6, 301-311

EIDE, M.S., SKJONG, R., LONGVA, T., ALVIK, S., ENDERSEN, Ø., 2009., (August). *Cost effectiveness assessment of CO_2 reducing measures in shipping*. Maritime Policy and Management, Vol. 36, No. 4, 367-384

DARBRA, R.M., PITTAM, N., ROYSTON, K.A., DARBRA, J.P., JOURNEE., 2009., (March). *Survey on environmental monitoring requirements of European ports*. Journal of Environmental Management, Vol. 90, No. 3, 1396-1403

TONGZON, J.L., SAWANT, L., 2009., (October). *Port choice in a competitive environment: from the shipping lines' perspective*. Applied Economics, Vol. 39, No. 4, 477-492

CORBETT, J.J., WANG, H., WINEBRAKE, J.J., 2009., (December). *The effectiveness and costs of speed reductions on emissions from international shipping*. Transportation Research Part D: Transport and Environment, Vol. 14, 593-598

MANGHAM, L.J., HANSON, K., Mc.PAKE, B., 2009., (March). *How to do (or not to do) …designing a discrete choice experiment for application in a low-income country*. Health Policy and Planning, Vol. 24, No. 2, 151-158

ADAMS, M., QUINONEZ, P., PALLIS, A.A., WAKEMAN T.H., 2009., (January). *Environmental issues in port competitiveness*. Dalhousie University, Atlantic Gateway Initiative, Center for International Trade and Transportation, Working Paper N. 7, 1-20

CHANG, Y.T., LEE, S.Y., TONGZON, J.L., 2008., (November). *Port selection factors by shipping lines: different perspectives between trunk liners and feeder service providers*. Marine Policy, Vol. 32, No. 6, 877-885

ENDERSEN, Ø., EIDE, M., DALSØREN, S., ISAKSEN, I., SØRGÅRD, E., 2008., (November). *The environmental impacts of increased international maritime shipping*. Global Forum on Transport and Environment in a Globalising World, Guadalajara, Mexico, 1-43

CASCETTA, E., 2006., (June). *Chapter 1: Modelli per i Sistemi di Trasporto: concetti preliminari e campi di applicazione., Chapter 3: Modelli di Utilità Aleatoria per la Simulazione dei Comportamenti di Scelta.* Modelli per i Sistemi di Trasporto: Teoria e Applicazioni, 22-29., 100-159

PATIL, R., GUPTA, A.K., GUPTA, S.K, 2005., (January). *Environmental management plan for port and harbour projects*. Clean Technologies and Environmental Policies, Vol. 7, No. 2, 133-141

GALLAGHER, K.P., 2005., (October). *International trade and air pollution: estimating the economic costs of air emissions from waterborne commerce vessels in the United States*. Journal of Environmental Management, Vol. 77, No. 2, 99-103

DARBRA, R.M., RONZA, A., STOJANOVIC, T.A., WOOLDRIDGE, C., CASAL, L., 2005., (August). *A procedure for identifying significant environmental aspects in sea ports*. Marine Pollution Bulletin, Vol. 50, No. 8, 866-874

MARCUCCI, E., SCACCIA, L., 2005. (February). *Alcune applicazioni dei modelli a scelta discreta al settore dei trasporti***.** I modelli di scelta discreta per l'analisi dei trasporti. Teoria, metodi ed applicazioni, 138-191

PERIS-MORA, E., DIEZ OREJAS, J.M., SUBIRATS, A., IBÁÑEZ, S., ALVAREZ, P., 2005., (December). *Development of a system of indicators for sustainable port management.* Marine Pollution Bulletin Vol. 50, No. 12, 1649-1660

BAILEY, D., SOLOMON G.M., 2004., (November). *Pollution prevention at ports: clearing the air*. Environmental Impact Assessment Review, Vol. 24, No. 8, 749-774

BAILEY, D., PLENYS, T., SOLOMON G.M., CAMPBELL, T.R., FEURE, G.R., MASTERS, J., TONKONOGY, B., 2004., (January). *Harbouring Pollution: strategies to clean up U.S. ports*. N.R.D.C The Earth's Best Defense. Online source: https://www.nrdc.org/sites/default/files/ports2.pdf

ENDERSEN, Ø., SØRGÅRD, E., DALSØREN, S., ISAKSEN, I., SUNDET, J.K., BERGLEN, F.T., GRAVIR, G., 2003., (September). *Emission from international sea transportation and environmental impact*. Journal of Geophysical Research, Vol. 108, No. D17, 1-22

TROZZI, C., VACCARO, R., 2000., (September). *Environmental impact of port activities*. Second International Ports 2000 Maritime Engineering and Ports, Barcelona, Spain. Online source:
https://www.researchgate.net/publication/236858102_Environmental_impact_of_port_activities

TUBIELEWICZ, A., 1995., (April). *Main environmental problems in seaports*. Bulletin of the Maritime Institute, Vol. 22, No. 1, 3-11

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT (UNCTAD), Geneva., 1975. *Port Pricing*.
Online source: https://unctad.org/en/PublicationsLibrary/tdbc4d110rev1_en.pdf

A-APPENDIX

The following table (Table Appendix 1.A) contains all the random combinations given from the software JMP when the design has been generated; these combinations will be necessary to build the questionnaire in the following steps.

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
2	1	10%	30%	-20%	GOOD	20%	EQUAL	MEDIUM
2	2	10%	EQUAL	-20%	BAD	10%	EQUAL	MEDIUM
3	1	EQUAL	-15%	EQUAL	BAD	-20%	-20%	MEDIUM
3	2	-10%	15%	20%	BAD	20%	-20%	MEDIUM
4	1	EQUAL	-30%	-20%	GOOD	20%	20%	MEDIUM
4	2	10%	30%	-20%	GOOD	EQUAL	EQUAL	MEDIUM
5	1	-20%	-15%	20%	GOOD	10%	EQUAL	EXTENDED
5	2	EQUAL	EQUAL	20%	GOOD	EQUAL	EQUAL	EXTENDED
6	1	-10%	30%	20%	MEDIUM	-10%	EQUAL	MEDIUM
6	2	10%	15%	EQUAL	GOOD	20%	20%	EXTENDED
7	1	-10%	-15%	20%	MEDIUM	EQUAL	EQUAL	MEDIUM
7	2	20%	15%	20%	MEDIUM	-10%	EQUAL	MEDIUM
8	1	10%	EQUAL	EQUAL	GOOD	-10%	20%	LIMITED
8	2	10%	EQUAL	EQUAL	GOOD	-10%	-20%	EXTENDED
9	1	EQUAL	30%	-20%	GOOD	10%	20%	EXTENDED
9	2	20%	-15%	-20%	GOOD	EQUAL	20%	EXTENDED
10	1	-20%	-30%	-20%	MEDIUM	-10%	-20%	EXTENDED
10	2	-20%	-30%	20%	GOOD	-10%	-20%	MEDIUM
11	1	10%	EQUAL	20%	MEDIUM	20%	20%	MEDIUM
11	2	-10%	15%	20%	GOOD	EQUAL	20%	EXTENDED
12	1	10%	30%	-20%	GOOD	20%	EQUAL	MEDIUM
12	2	10%	30%	EQUAL	MEDIUM	20%	EQUAL	EXTENDED
13	1	20%	30%	EQUAL	BAD	20%	-20%	LIMITED
13	2	20%	EQUAL	EQUAL	MEDIUM	10%	-20%	LIMITED
14	1	-10%	30%	EQUAL	BAD	-20%	20%	MEDIUM
14	2	EQUAL	-15%	20%	BAD	-20%	EQUAL	EXTENDED
15	1	-10%	15%	20%	GOOD	-20%	EQUAL	MEDIUM
15	2	EQUAL	-15%	EQUAL	GOOD	-10%	EQUAL	MEDIUM

16	1	EQUAL	15%	-20%	MEDIUM	EQUAL	-20%	MEDIUM
16	2	-10%	EQUAL	-20%	GOOD	-10%	-20%	EXTENDED
17	1	10%	-15%	20%	BAD	10%	EQUAL	EXTENDED
17	2	-20%	EQUAL	20%	BAD	EQUAL	EQUAL	EXTENDED
18	1	-10%	-30%	-20%	MEDIUM	20%	-20%	LIMITED
18	2	-10%	-30%	-20%	MEDIUM	20%	20%	MEDIUM
19	1	20%	-30%	EQUAL	MEDIUM	20%	EQUAL	EXTENDED
19	2	10%	-30%	20%	MEDIUM	-10%	20%	EXTENDED
20	1	20%	30%	20%	MEDIUM	10%	20%	MEDIUM
20	2	-10%	15%	EQUAL	MEDIUM	-10%	EQUAL	MEDIUM

Table Appendix 1.A *Random combinations for the survey from JMP (Source: JMP)*

In the table (Table Appendix 1.A) is possible to see the columns of the attributes with their different combinations and the first two columns are the “choice set” and the “choice ID”.

The choice set is the number of the question in the survey.

The choice ID (always 1 and 2) is the choice Port A (1) or the choice Port B (2).

B-APPENDIX

Here in this Appendix, is reported all the questionnaire in the same faithful form it has been distributed to the shipping companies.
Are also included information about the authors of the research to specify to the companies how we operated.

DCA SURVEY FOR PORT GREENING CONCEPT DEVELOPMENT

Brief introduction of the work

The following questionnaire is to clarify decision-making on "port greening".
Under the supervision of Prof. Thierry Vanelslander at University of Antwerp (Department of Transport and Regional Economics), in Belgium, it has been decided to undertake this project to understand what the most influential factors and indicators in a green shipping port environment are. The analysis is based on the question*: "How do container shipping companies choose their ports for cargo operations, taking into account port greening as much as possible?"*

The results of the DCA (questionnaire with related answers) will be analyzed using a multinomial logit model (MNL) which is based on random utility theory, namely the utility that a respondent attaches to alternatives to an alternative in a choice set.
It is significant to underline that the analysis of the results will be conducted using a software called JMP, which is the same software that gave us the combination shown in the following questions of the survey.
The pursuit of the whole analysis 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 huge control on the willingness and decision to choose which port to dock or not by a shipping company.

The following analysis and the consequent project developed around this topic will be the main central topic of the MSc Thesis of Lorenzo Franchi. He is an Italian student who attended

Master Degree in Transport Systems Engineering at Sapienza University in Rome and who has been invited and hosted, to work on his final thesis project, at the University of Antwerp thanks to Prof. T. Vanelslander.

INTRODUCTION TO THE QUESTIONNAIRE

The following questionnaire is composed of **21 questions**.

The questionnaire has been built using a software called Qualtrics.

- The first 20 choice set has the same request at the basic. In every choice set changes the combination of the levels of attributes according to what is explained before.

Please read every choice (Port A and Port B) and try to tick the most suitable for you.

Please, read also the document submitted, in which are explained and reported the combinations of the levels of attribute for determining the choice sets.

- In question 21 please try, if you want, briefly and in a few words, to indicate or illustrate what is requested.

QUESTION 1

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?

	• 10% higher port charges • 30% lower air pollution • 20% lower noise pollution • Average restrictions on water pollution • Equal port resource consumption compared with the current situation	• Equal port charges compared with the current situation • 15% lower air pollution • 20% lower noise pollution • Average restrictions on water pollution • 20% higher port resource consumption

	• Equal port capacity and productivity compared with the current situation • Low degree of development and improvement	• 20% higher port capacity and productivity • Low degree of development
	PORT A ○	***PORT B*** ○

QUESTION 2

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?

	• 10% higher port charges • 30% higher air pollution • 20% lower noise pollution • High restrictions on water pollution • 20% higher port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement	• 10% higher port charges • Equal air pollution, average density of emissions allowed • 20% lower noise pollution • Low restrictions on water pollution • 10% higher port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement
	PORT A ○	***PORT B*** ○

QUESTION 3

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?

	• Equal port charges compared with the current situation	• 10% lower port charges • 15% higher air pollution

	PORT A	PORT B
	• 15% lower air pollution • Equal noise pollution, average degree of noise pollution allowed • Low restrictions on water pollution • 20% lower port resource consumption • 20% lower port capacity and productivity • Average degree of development and improvement	• 20% higher noise pollution • Low restrictions on water pollution • 20% higher port resource consumption • 20% lower port capacity and productivity • Average degree of development and improvement
	○	○

QUESTION 4

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?

	PORT A	PORT B
	• Equal port charges compared with the current situation • 30% lower air pollution • 20% lower noise pollution • High restrictions on water pollution • 20% higher port resource consumption • 20% higher port capacity and productivity • Average degree of development and improvement	• 10% higher port charges • 30% higher air pollution • 20% lower noise pollution • High restrictions on water pollution • Equal port resource consumption compared with the current situation • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement
	○	○

QUESTION 5

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?

	PORT A	PORT B
	• 20% lower port charges • 15% lower air pollution • 20% higher noise pollution • High restrictions on water pollution • 10% higher port resource consumption • Equal port capacity and productivity compared with the current situation • High degree of development and improvement	• Equal port charges compared with the current situation • Equal air pollution, average density of emission allowed • 20% higher noise pollution • High restrictions on water pollution • Equal port resource consumption compared with the current situation • Equal port capacity and productivity compared with the current situation • High degree of development and improvement
	○	○

QUESTION 6

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?

	• 10% lower port charges • 30% higher air pollution • 20% higher noise pollution • Average restrictions on water pollution • 10% lower port resource consumption • Equal port capacity and productivity compared with the current situation	• 10% higher port charges • 15% higher air pollution • Equal noise pollution, average degree of noise pollution allowed • High restrictions on water pollution • 20% higher port resource consumption • 20% higher port capacity and productivity

	• Average degree of development and improvement	• High degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 7

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?

	• 10% lower port charges • 15% lower air pollution • 20% higher noise pollution • Average restrictions on water pollution • Equal port resource consumption compared with the current situation • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement	• 20% higher port charges • 15% higher air pollution • 20% higher noise pollution • Average restrictions on water pollution • 10% lower port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 8

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?

	• 10% higher port charges • Equal air pollution, average density of emissions allowed	• 10% higher port charges • Equal air pollution, average density of emissions allowed

	• Equal noise pollution, average degree of noise pollution allowed • High restrictions on water pollution • 10% lower port resource consumption • 20% higher port capacity and productivity • Low degree of development and improvement	• Equal noise pollution, average degree of noise pollution allowed • High restrictions on water pollution • 10% lower port resource consumption • 20% lower port capacity and productivity • High degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 9

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?

	• Equal port charges compared with the current situation • 30% higher air pollution • 20% lower noise pollution • Average restrictions on water pollution • 10% higher port resource consumption • 20% higher port capacity and productivity • High degree of development and improvement	• 20% higher port charges • 15% lower air pollution • 20% lower noise pollution • High restrictions on water pollution • Equal port resource consumption compared with the current situation • 20% higher port capacity and productivity • High degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 10

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?

	PORT A	PORT B
	• 20% lower port charges • 30% lower air pollution • 20% lower noise pollution • Average restrictions on water pollution • 10% lower port resource consumption • 20% lower port capacity and productivity • High degree of development and improvement	• 20% lower port charges • 30% lower air pollution • 20% higher noise pollution • High restrictions on water pollution • 10% lower port resource consumption • 20% lower port capacity and productivity • Average degree of development and improvement
	○	○

QUESTION 11

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?

	PORT A	PORT B
	• 10% higher port charges • Equal air pollution, average density of emissions allowed • 20% higher noise pollution • Average restrictions on water pollution • 20% higher port resource consumption • 20% higher port capacity and productivity • Average degree of development and improvement	• 10% lower port charges • 15% higher air pollution • 20% higher noise pollution • High restrictions on water pollution • Equal port resource consumption compared with the current situation • 20% higher port capacity and productivity • High degree of development and improvement

QUESTION 12

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?

	• 10% higher port charges • 30% higher air pollution • 20% lower noise pollution • Average restrictions on water pollution • 20% higher port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement	• 10% higher port charges • 30% higher air pollution • Equal noise pollution, average degree of noise pollution allowed • Average restrictions on water pollution • 20% higher port resource consumption • Equal port capacity and productivity compared with the current situation • High degree of development and improvement
	PORT A	***PORT B***

QUESTION 13

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?

	• 20% higher port charges • 30% higher air pollution • Equal noise pollution, average degree of noise pollution allowed • Low restrictions on water pollution • 20% higher port resource consumption • 20% lower port capacity and productivity	• 20% higher port charges • Equal air pollution, average density of emissions allowed • Equal noise pollution, average degree of noise pollution allowed • Average restrictions on water pollution

	• Low degree of development and improvement	• 10% higher port resource consumption • 20% lower port capacity and productivity • Low degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 14

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?

	• 10% lower port charges • 30% higher air pollution • Equal noise pollution, average degree of noise pollution allowed • Low restrictions on water pollution • 20% lower port resource consumption • 20% higher port capacity and productivity • Average degree of development and improvement	• Equal port charges, compared with the current situation • 15% lower air pollution • 20% higher noise pollution • Low restrictions on water pollution • 20% lower port resource consumption • Equal port capacity and productivity compared with the current situation • High degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 15

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?

	PORT A	PORT B
	• 10% lower port charges • 15% higher air pollution • 20% higher noise pollution • Average restrictions on water pollution • 20% lower port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement	• Equal port charges compared with the current situation • 15% lower air pollution • Equal noise pollution, average degree of noise pollution allowed • Average restrictions on water pollution • 10% lower port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement
	○	○

QUESTION 16

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?

	• Equal port charges compared with the current situation • 15% higher air pollution • 20% lower noise pollution • Average restrictions on water pollution • Equal port resource consumption compared with the current situation • 20% lower port capacity and productivity	• 10% lower port charges • Equal air pollution, average density of emissions allowed • 20% lower noise pollution • Average restrictions on water pollution • 10% lower port resource consumption • 20% lower port capacity and productivity • High degree of development and improvement

	• Average degree of development and improvement	
	PORT A ○	***PORT B*** ○

QUESTION 17

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?

	• 10% higher port charges • 15% lower air pollution • 20% higher noise pollution • Low restrictions on water pollution • 10% higher port resource consumption • Equal port capacity and productivity compared with the current situation • High degree of development and improvement	• 20% lower port charges • Equal air pollution, average degree of emissions allowed • 20% higher noise pollution • Low restrictions on water pollution • Equal port resource consumption compared with the current situation • Equal port capacity and productivity compared with the current situation • High degree of development and improvement
	PORT A ○	***PORT B*** ○

QUESTION 18

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?

	• 10% lower port charges • 30% lower air pollution • 20% lower noise pollution	• 10% lower port charges • 30% lower air pollution • 20% lower noise pollution

	• Average restrictions on water pollution • 20% higher port resource consumption • 20% lower port capacity and productivity • Low degree of development and improvement	• Average restrictions on water pollution • 20% higher port resource consumption • 20% higher port capacity and productivity • Average degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 19

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?

	• 20% higher port charges • 30% lower air pollution • Equal noise pollution, average degree of noise pollution allowed • Average restrictions on water pollution • 20% higher port resource consumption • Equal port capacity and productivity compared with the current situation • High degree of development and improvement	• 10% higher port charges • 30% lower air pollution • 20% higher noise pollution • Average restrictions on water pollution • 10% lower port resource consumption • 20% higher port capacity and productivity • High degree of development and improvement
	PORT A	***PORT B***
	○	○

QUESTION 20

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?

	• 20% higher port charges • 30% higher air pollution	• 10% lower port charges • 15% higher air pollution

	• 20% higher noise pollution • Average restrictions on water pollution • 10% higher port resource consumption • 20% higher port capacity and productivity • Average degree of development and improvement	• Equal noise pollution, average degree of noise pollution allowed • Average restrictions on water pollution • 10% lower port resource consumption • Equal port capacity and productivity compared with the current situation • Average degree of development and improvement
	PORT A ○	***PORT B*** ○

QUESTION 21

Based on the answer given in the previous questions, would you know, according to your experience, to indicate which would be the most appropriate management measure to keep the green port parameter under control?

____
____
____
____
____
____

C-APPENDIX

The results of the questionnaire (Table Appendix 2.C) and the example of the response to the survey by Arkas Lines are shown in this Appendix.
The interview with Arkas Lines has been conducted in an indirect way, via email. Here, will be shown the document released by the company via email.

Response to the survey by Arkas Lines

Here follows the response to the questionnaire by Arkas Lines. We have reported the exact document they provided us, with their replies to the first 20 questions and also the answer to the 21st open question.

Response to the survey

Dear Mr. Lorenzo Franchi, here our document about the response to your survey.
Capt. Kusuv (asst. gm responsible from the procurement of Arkas Line) has been very helpful in the preparation of this document.
We hope it will help your research.

1 – B

2 – B

3 – B

4 – A

5 – A

6 – A

7 – A

8 – A

9 – A

10 – A

11 – B

12 – A

13 – B

14 – A

15 – A

16 – B

17 – B

18 – B

19 – B

20 – B

21 – Recently all shipping lines and carriers are struggling against huge financial losses due to high fuel prices and low freight rates on the contrary. Cost is the main driver for carriers and unless restricted by local authority or organization, liners prefer to use most economical and efficient resources and services to keep their expenditures under control. We can not 100 % identify a single criterion to be kept under control or developed. It depends on what a line needs in a specific port or region. If the priority is to keep cost under control, surely a cheaper terminal will be concluded, however, that terminal should be capable of handling vessel by size and equipment. Also, choosing a cheaper alternative may end up with higher loss due to lower productivity and longer steaming time or higher fuel consumption. In your study, the priority of a line/customer is not clearly defined, thus even same colleagues in a company can give different answers due to the need of their route, trade, equipment and fleet. However, as mentioned in the first sentence, we may predict cost and charges as main driver for decisions on terminals.

Addition to above, majority of terminal operators and liners are obliged to comply with average necessities in terms of environmental care and labour rights as per client's requirements like IKEA, APPLE and similar global corporations.

All other responses to the survey

Here are reported all the other responses by all the companies (Arkas Lines is included). It is mentioned just Arkas Lines, the other companies are not mentioned because of matter of privacy.

Of course, the order in which are presented the respondents is not the same as the presented companies in the chapter dedicated to the data collection.

RESPONDENT	COMPANY ID	CHOICE SET	RESPONSE
1	PRIVACY	1	1
1	PRIVACY	1	0
1	PRIVACY	2	0
1	PRIVACY	2	1
1	PRIVACY	3	1
1	PRIVACY	3	0
1	PRIVACY	4	1
1	PRIVACY	4	0
1	PRIVACY	5	1
1	PRIVACY	5	0
1	PRIVACY	6	0
1	PRIVACY	6	1
1	PRIVACY	7	1
1	PRIVACY	7	0
1	PRIVACY	8	1
1	PRIVACY	8	0
1	PRIVACY	9	0
1	PRIVACY	9	1
1	PRIVACY	10	0
1	PRIVACY	10	1
1	PRIVACY	11	1
1	PRIVACY	11	0
1	PRIVACY	12	0
1	PRIVACY	12	1
1	PRIVACY	13	0
1	PRIVACY	13	1
1	PRIVACY	14	0
1	PRIVACY	14	1
1	PRIVACY	15	0
1	PRIVACY	15	1

1	PRIVACY	16	0
1	PRIVACY	16	1
1	PRIVACY	17	1
1	PRIVACY	17	0
1	PRIVACY	18	0
1	PRIVACY	18	1
1	PRIVACY	19	0
1	PRIVACY	19	1
1	PRIVACY	20	0
1	PRIVACY	20	1
2	PRIVACY	1	1
2	PRIVACY	1	0
2	PRIVACY	2	0
2	PRIVACY	2	1
2	PRIVACY	3	0
2	PRIVACY	3	1
2	PRIVACY	4	1
2	PRIVACY	4	0
2	PRIVACY	5	1
2	PRIVACY	5	0
2	PRIVACY	6	1
2	PRIVACY	6	0
2	PRIVACY	7	1
2	PRIVACY	7	0
2	PRIVACY	8	0
2	PRIVACY	8	1
2	PRIVACY	9	1
2	PRIVACY	9	0
2	PRIVACY	10	1
2	PRIVACY	10	0
2	PRIVACY	11	0
2	PRIVACY	11	1
2	PRIVACY	12	0
2	PRIVACY	12	1
2	PRIVACY	13	0
2	PRIVACY	13	1
2	PRIVACY	14	1
2	PRIVACY	14	0
2	PRIVACY	15	1
2	PRIVACY	15	0
2	PRIVACY	16	0
2	PRIVACY	16	1

2	PRIVACY	17	0
2	PRIVACY	17	1
2	PRIVACY	18	0
2	PRIVACY	18	1
2	PRIVACY	19	0
2	PRIVACY	19	1
2	PRIVACY	20	0
2	PRIVACY	20	1
3	PRIVACY	1	1
3	PRIVACY	1	0
3	PRIVACY	2	0
3	PRIVACY	2	1
3	PRIVACY	3	1
3	PRIVACY	3	0
3	PRIVACY	4	1
3	PRIVACY	4	0
3	PRIVACY	5	1
3	PRIVACY	5	0
3	PRIVACY	6	0
3	PRIVACY	6	1
3	PRIVACY	7	1
3	PRIVACY	7	0
3	PRIVACY	8	1
3	PRIVACY	8	0
3	PRIVACY	9	0
3	PRIVACY	9	1
3	PRIVACY	10	0
3	PRIVACY	10	1
3	PRIVACY	11	1
3	PRIVACY	11	0
3	PRIVACY	12	0
3	PRIVACY	12	1
3	PRIVACY	13	0
3	PRIVACY	13	1
3	PRIVACY	14	0
3	PRIVACY	14	1
3	PRIVACY	15	0
3	PRIVACY	15	1
3	PRIVACY	16	0
3	PRIVACY	16	1
3	PRIVACY	17	1
3	PRIVACY	17	0

3	PRIVACY	18	0
3	PRIVACY	18	1
3	PRIVACY	19	0
3	PRIVACY	19	1
3	PRIVACY	20	0
3	PRIVACY	20	1
4	PRIVACY	1	0
4	PRIVACY	1	1
4	PRIVACY	2	0
4	PRIVACY	2	1
4	PRIVACY	3	1
4	PRIVACY	3	0
4	PRIVACY	4	1
4	PRIVACY	4	0
4	PRIVACY	5	0
4	PRIVACY	5	1
4	PRIVACY	6	0
4	PRIVACY	6	1
4	PRIVACY	7	0
4	PRIVACY	7	1
4	PRIVACY	8	0
4	PRIVACY	8	1
4	PRIVACY	9	0
4	PRIVACY	9	1
4	PRIVACY	10	1
4	PRIVACY	10	0
4	PRIVACY	11	0
4	PRIVACY	11	1
4	PRIVACY	12	0
4	PRIVACY	12	1
4	PRIVACY	13	0
4	PRIVACY	13	1
4	PRIVACY	14	0
4	PRIVACY	14	1
4	PRIVACY	15	1
4	PRIVACY	15	0
4	PRIVACY	16	0
4	PRIVACY	16	1
4	PRIVACY	17	1
4	PRIVACY	17	0
4	PRIVACY	18	0
4	PRIVACY	18	1

4	PRIVACY	19	0
4	PRIVACY	19	1
4	PRIVACY	20	1
4	PRIVACY	20	0
5	ARKAS LINES	1	0
5	ARKAS LINES	1	1
5	ARKAS LINES	2	0
5	ARKAS LINES	2	1
5	ARKAS LINES	3	0
5	ARKAS LINES	3	1
5	ARKAS LINES	4	1
5	ARKAS LINES	4	0
5	ARKAS LINES	5	1
5	ARKAS LINES	5	0
5	ARKAS LINES	6	1
5	ARKAS LINES	6	0
5	ARKAS LINES	7	1
5	ARKAS LINES	7	0
5	ARKAS LINES	8	1
5	ARKAS LINES	8	0
5	ARKAS LINES	9	1
5	ARKAS LINES	9	0
5	ARKAS LINES	10	1
5	ARKAS LINES	10	0
5	ARKAS LINES	11	0
5	ARKAS LINES	11	1
5	ARKAS LINES	12	1
5	ARKAS LINES	12	0
5	ARKAS LINES	13	0
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5	ARKAS LINES	14	1
5	ARKAS LINES	14	0
5	ARKAS LINES	15	1
5	ARKAS LINES	15	0
5	ARKAS LINES	16	0
5	ARKAS LINES	16	1
5	ARKAS LINES	17	0
5	ARKAS LINES	17	1
5	ARKAS LINES	18	0
5	ARKAS LINES	18	1
5	ARKAS LINES	19	0
5	ARKAS LINES	19	1

5	ARKAS LINES	20	0
5	ARKAS LINES	20	1
6	PRIVACY	1	1
6	PRIVACY	1	0
6	PRIVACY	2	0
6	PRIVACY	2	1
6	PRIVACY	3	0
6	PRIVACY	3	1
6	PRIVACY	4	1
6	PRIVACY	4	0
6	PRIVACY	5	1
6	PRIVACY	5	0
6	PRIVACY	6	1
6	PRIVACY	6	0
6	PRIVACY	7	1
6	PRIVACY	7	0
6	PRIVACY	8	0
6	PRIVACY	8	1
6	PRIVACY	9	1
6	PRIVACY	9	0
6	PRIVACY	10	1
6	PRIVACY	10	0
6	PRIVACY	11	0
6	PRIVACY	11	1
6	PRIVACY	12	0
6	PRIVACY	12	1
6	PRIVACY	13	0
6	PRIVACY	13	1
6	PRIVACY	14	1
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6	PRIVACY	15	1
6	PRIVACY	15	0
6	PRIVACY	16	0
6	PRIVACY	16	1
6	PRIVACY	17	0
6	PRIVACY	17	1
6	PRIVACY	18	0
6	PRIVACY	18	1
6	PRIVACY	19	0
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***Table Appendix 2.C** Survey's responses by companies (Source: own composition).*

D-APPENDIX

In this section are reported all the charts that belong to the first part of the analysis of the results, and the script JMP used to implement the model.

```
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	Choice Set ID( :Choice Set ),
	Profile ID( :Response ),
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		:COST AND CHARGES,
		:AIR POLLUTION,
		:NOISE POLLUTION,
		:WATER POLLUTION,
		:RESOURCE CONSUMPTION,
		:PORT CAPACITY AND PRODUCTIVITY,
		:PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT
	),
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	Likelihood Ratio Tests( 1 ),
	Confidence Intervals( 1 ),
	Utility Profiler(
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		Confidence Intervals( 1 ),
		Reorder X Variables(
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			:AIR POLLUTION,
			:NOISE POLLUTION,
			:WATER POLLUTION,
			:RESOURCE CONSUMPTION,
			:PORT CAPACITY AND PRODUCTIVITY,
			:PORT ENVIRONMENTAL IMPROVEMENT AND DEVELOPMENT
		),
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			WATER POLLUTION( "GOOD", Lock( 0 ), Show( 1 ) ),
			RESOURCE CONSUMPTION( "+20%", Lock( 0 ), Show( 1 ) ),
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"Effect Summary Charts" – "Parameter Estimates Charts" – "Likelihood Ratio Test Chart"- "Marginal Utility Charts"

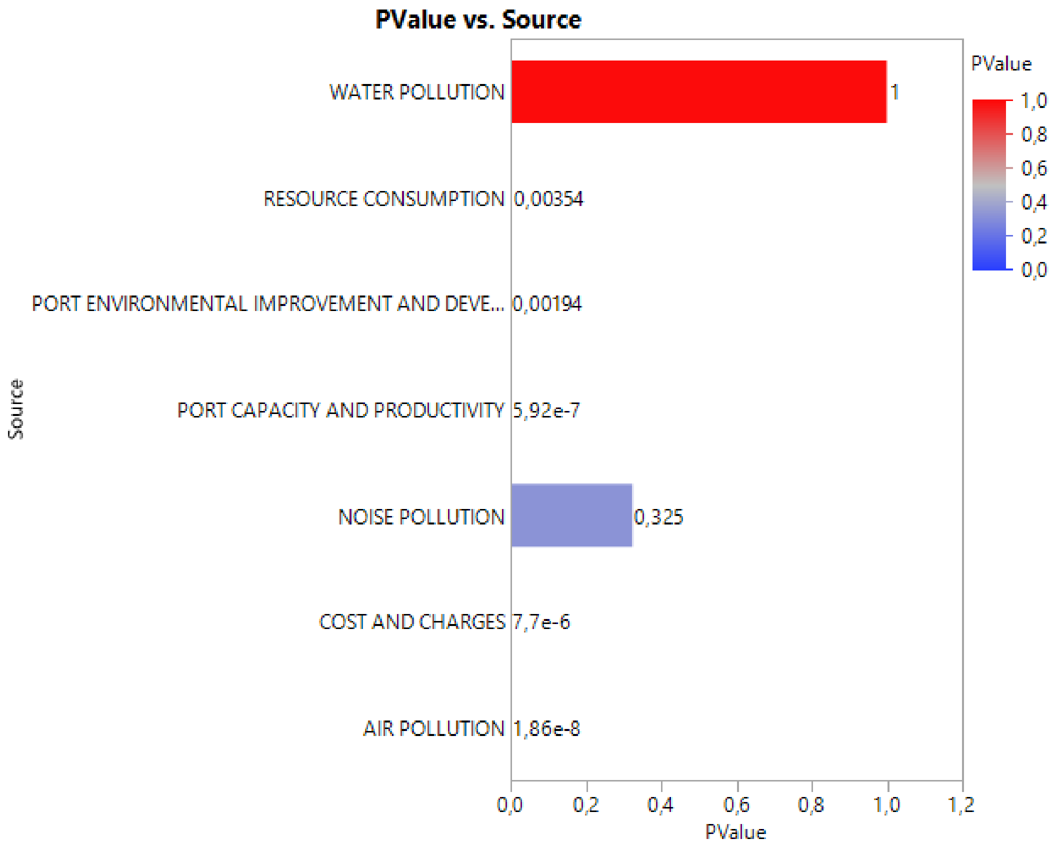

***Figure Appendix 1.D** Source-P-values (Source: JMP)*

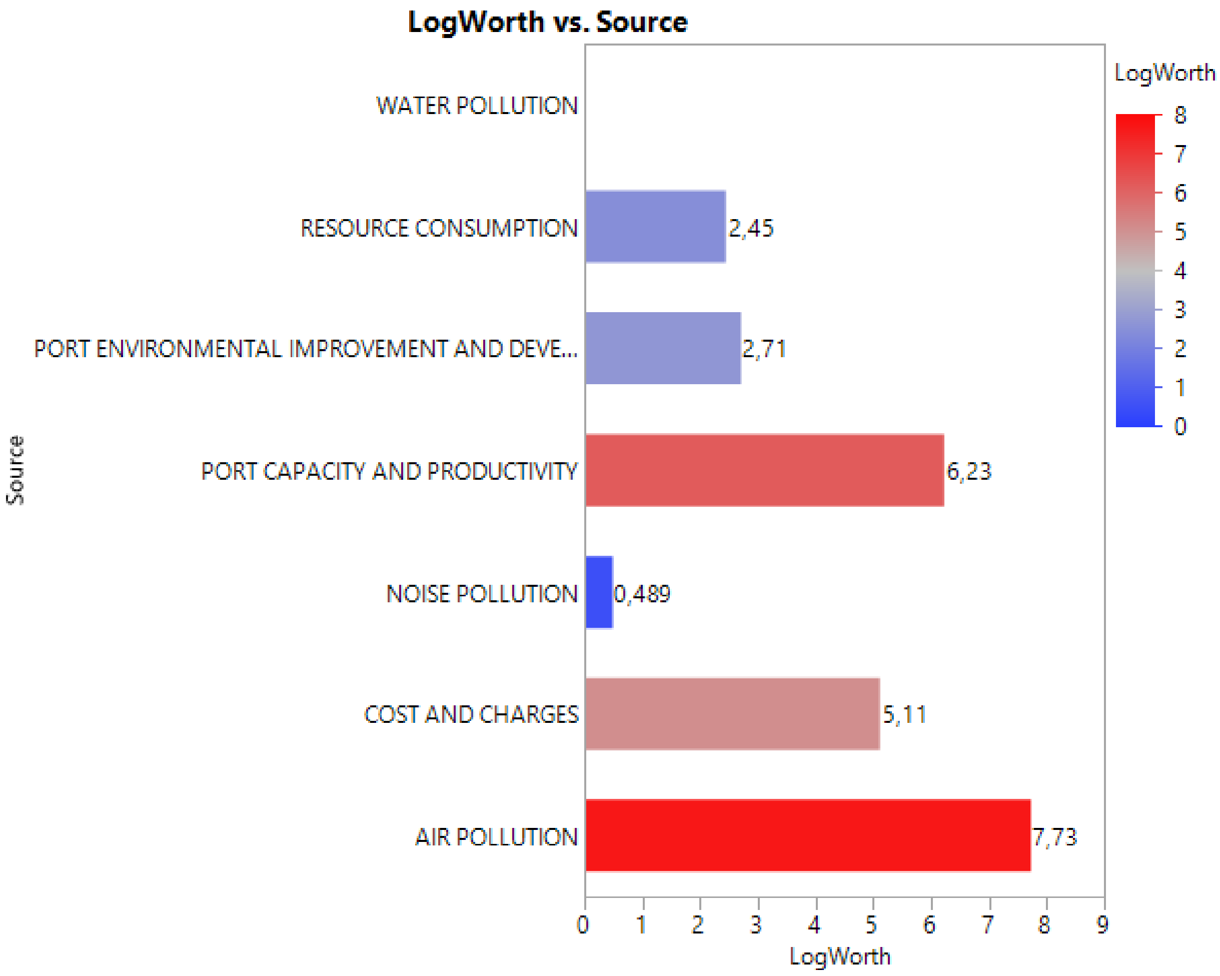

Figure Appendix 2.D *Source- LogWorth (Source: JMP)*

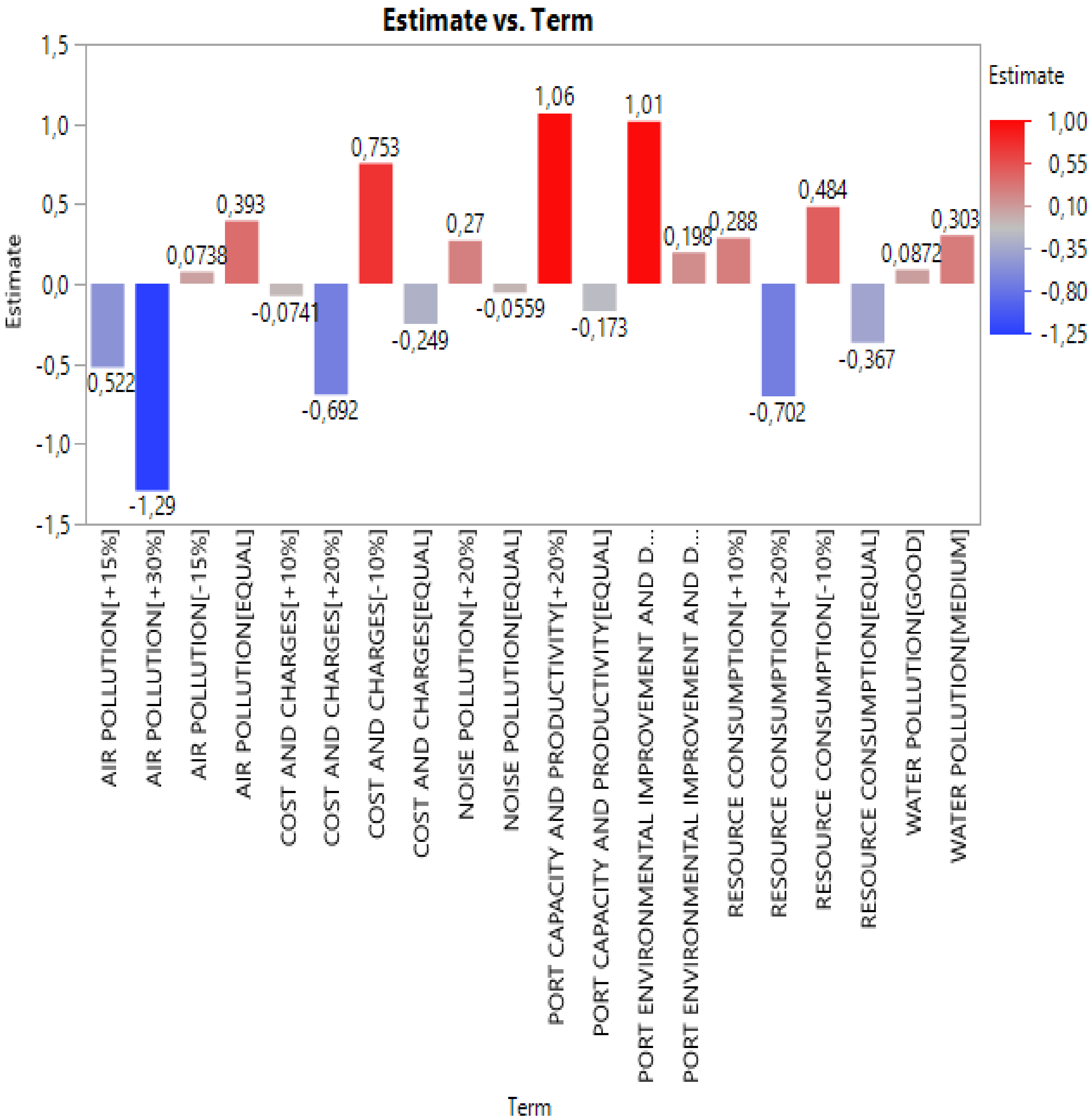

Figure Appendix 3.D *Estimate Parameters-Term (attributes' levels) (Source: JMP)*

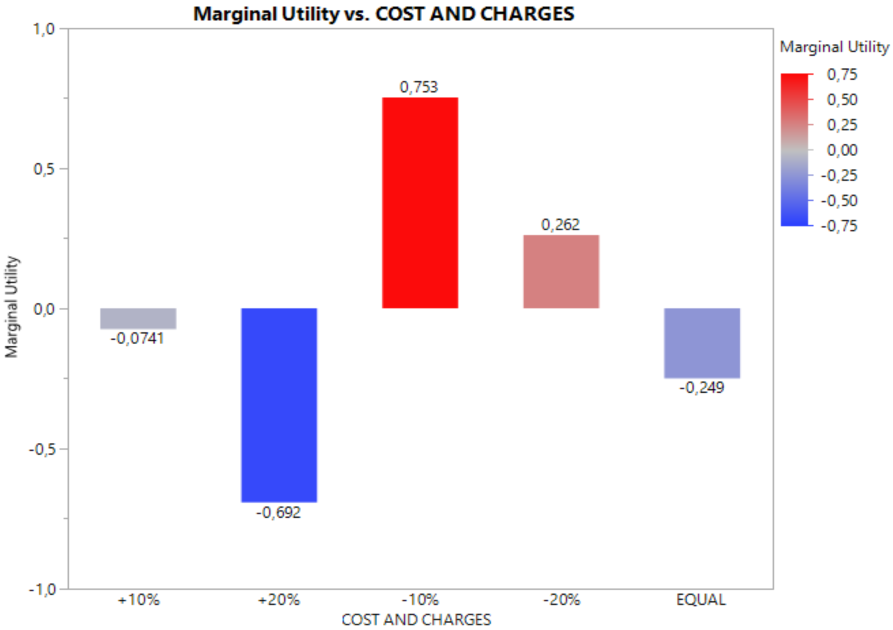

Figure Appendix 4.D *Marginal utility Cost and Charges (Source: JMP)*

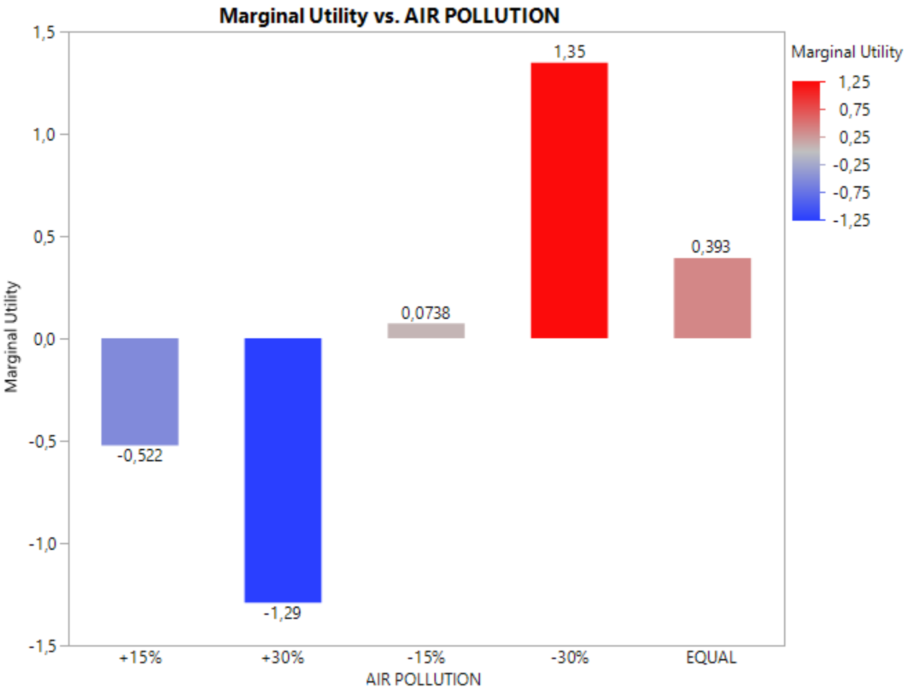

Figure Appendix 5.D *Marginal utility Air Pollution (Source: JMP)*

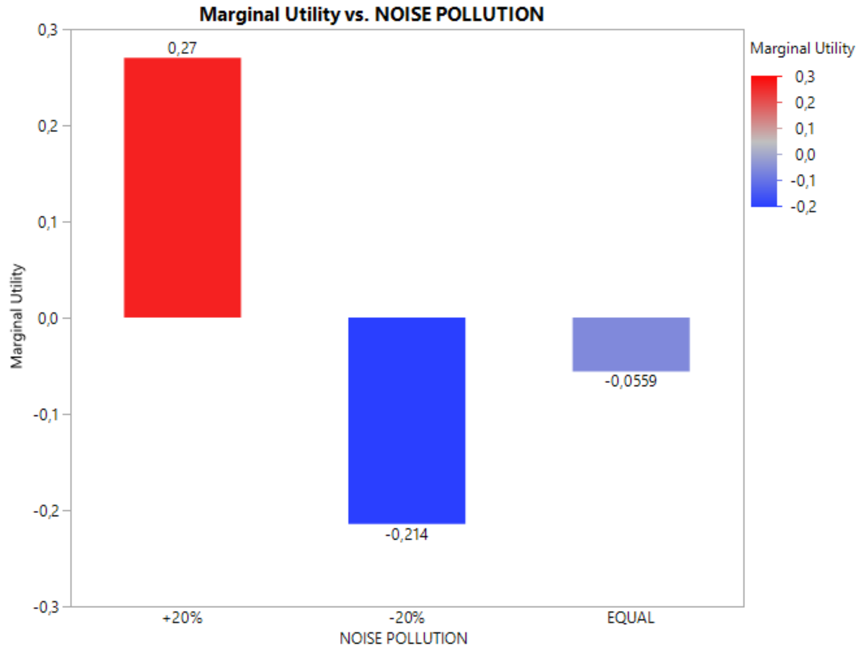

Figure Appendix 6.D *Marginal utility Noise Pollution (Source: JMP)*

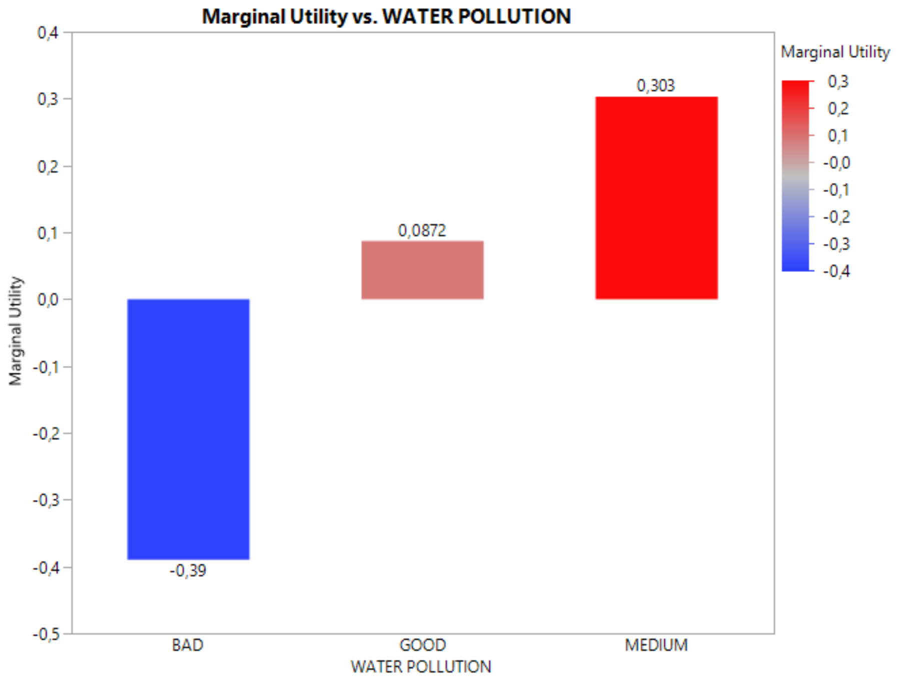

Figure Appendix 7.D *Marginal utility Water Pollution (Source: JMP)*

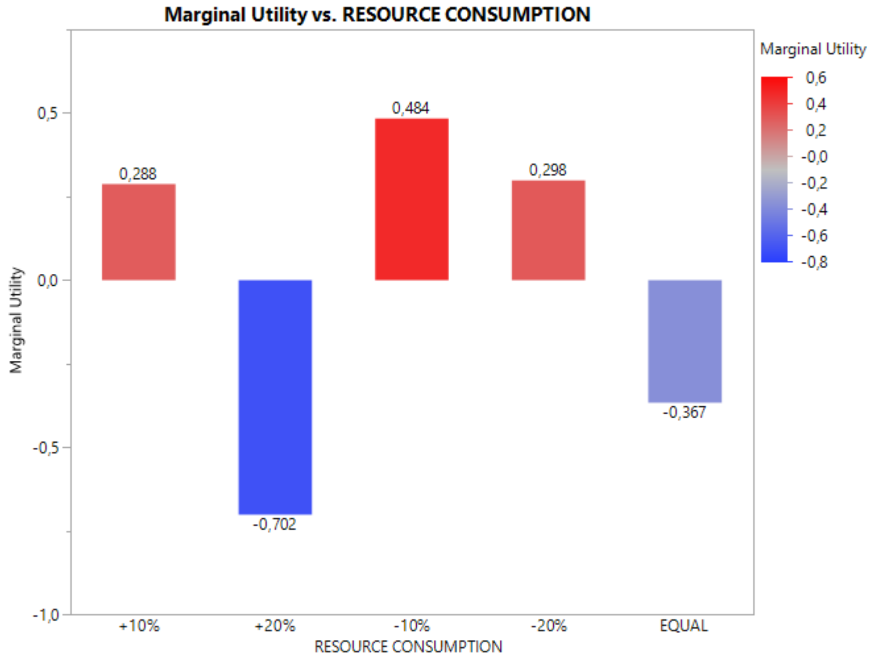

***Figure Appendix 8.D** Marginal utility Resource Consumption (Source: JMP)*

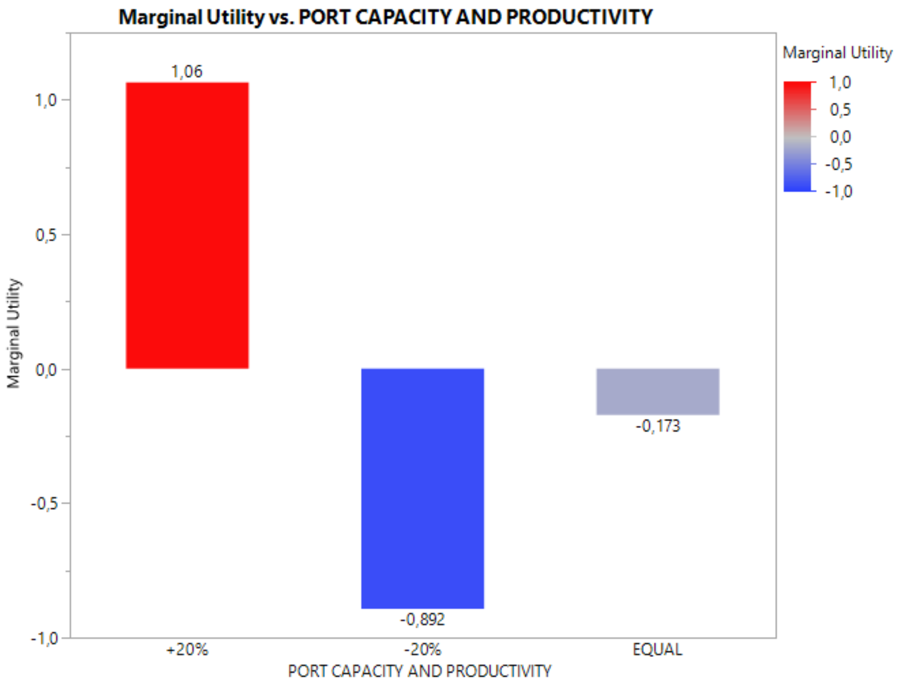

***Figure Appendix 9.D** Marginal utility Port Capacity and Productivity (Source: JMP)*

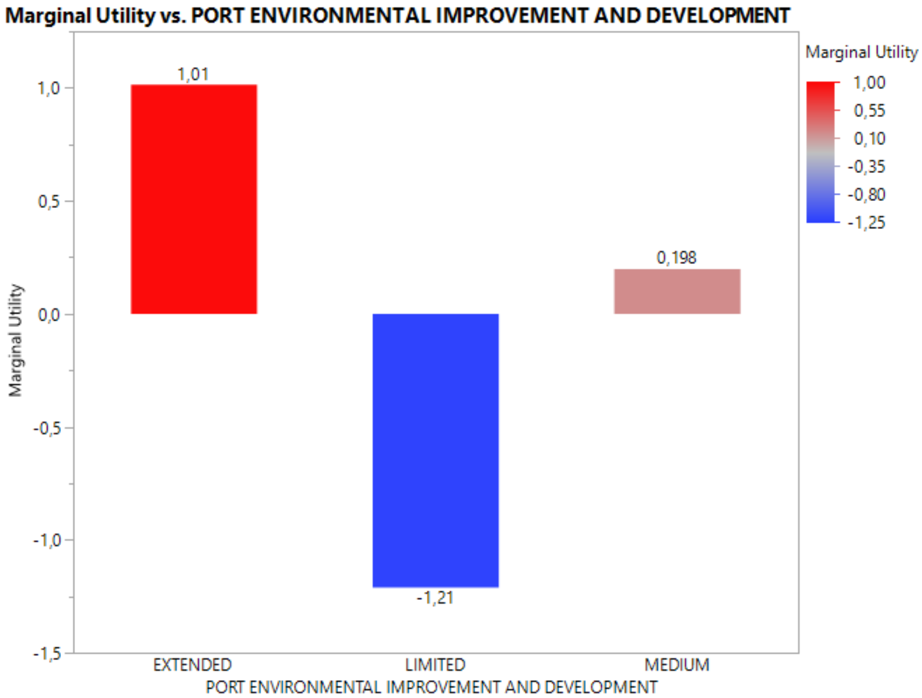

Figure Appendix 10.D *Marginal utility Port Environmental Improvement and Development (Source: JMP)*

"Effect Summary Charts" – "Parameter Estimates Charts" – "Likelihood Ratio Test Chart"- "Marginal Utility Charts" for the three attributes (Water Pollution, Noise Pollution and Resource Consumption)

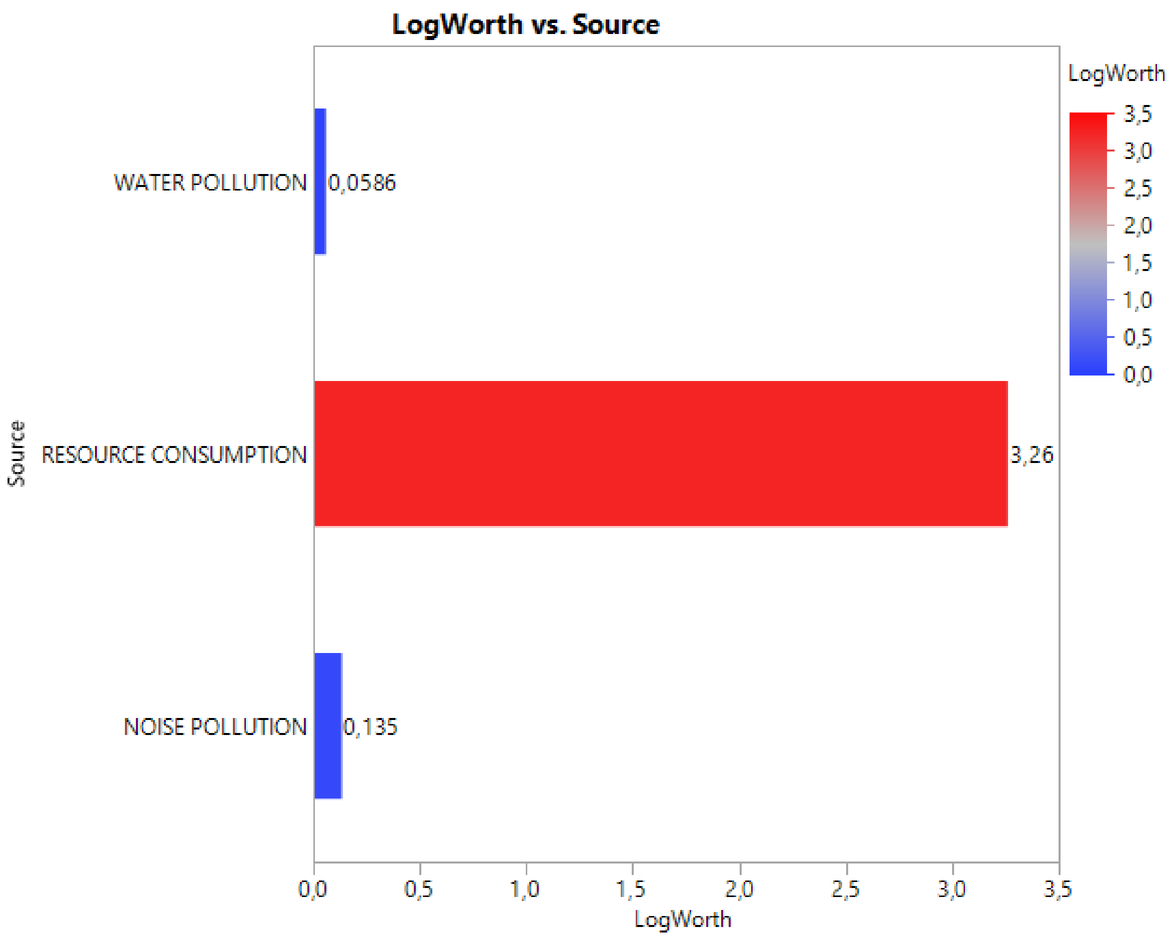

Figure Appendix 11.D *Source – LogWorth for the three attributes (Source: JMP)*

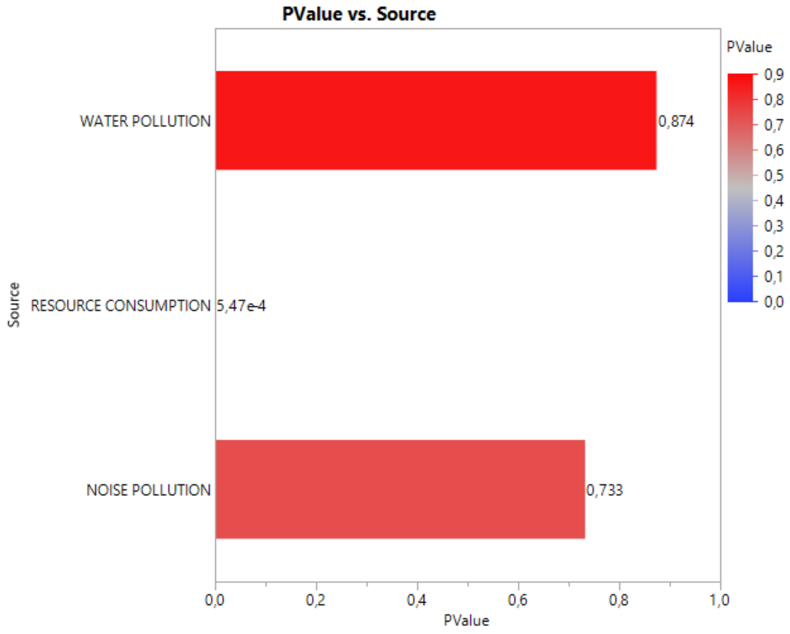

Figure Appendix 12.D *Source – P-values for the three attributes (Source: JMP)*

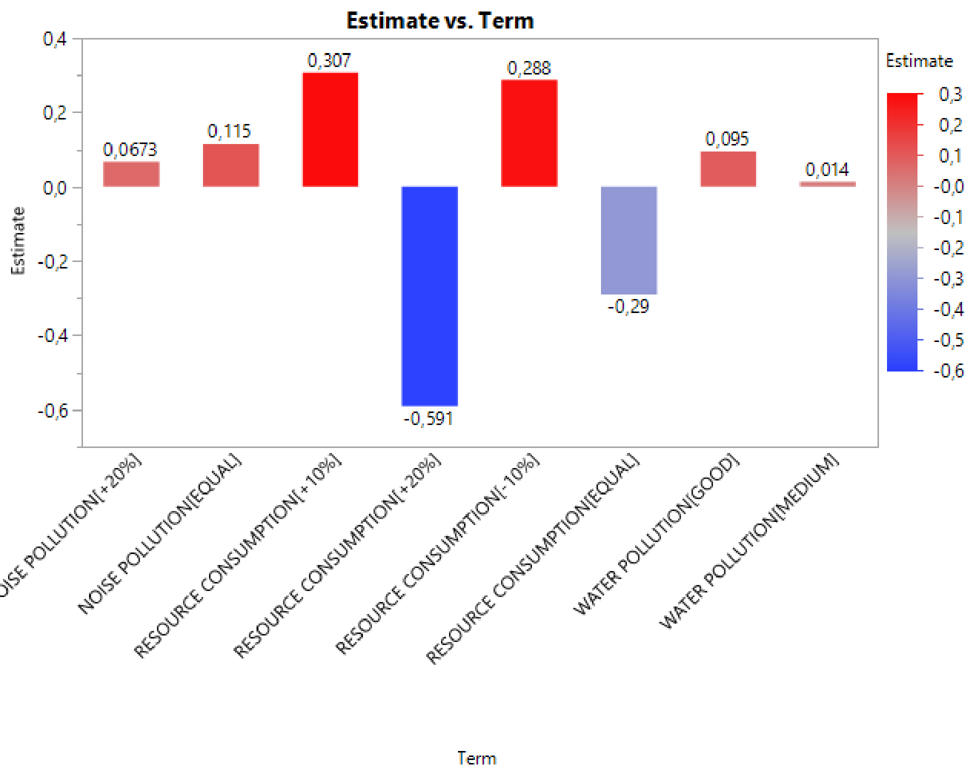

Figure Appendix 13.D *Estimate Parameters - Term (attributes' levels for the three attributes) (Source: JMP)*

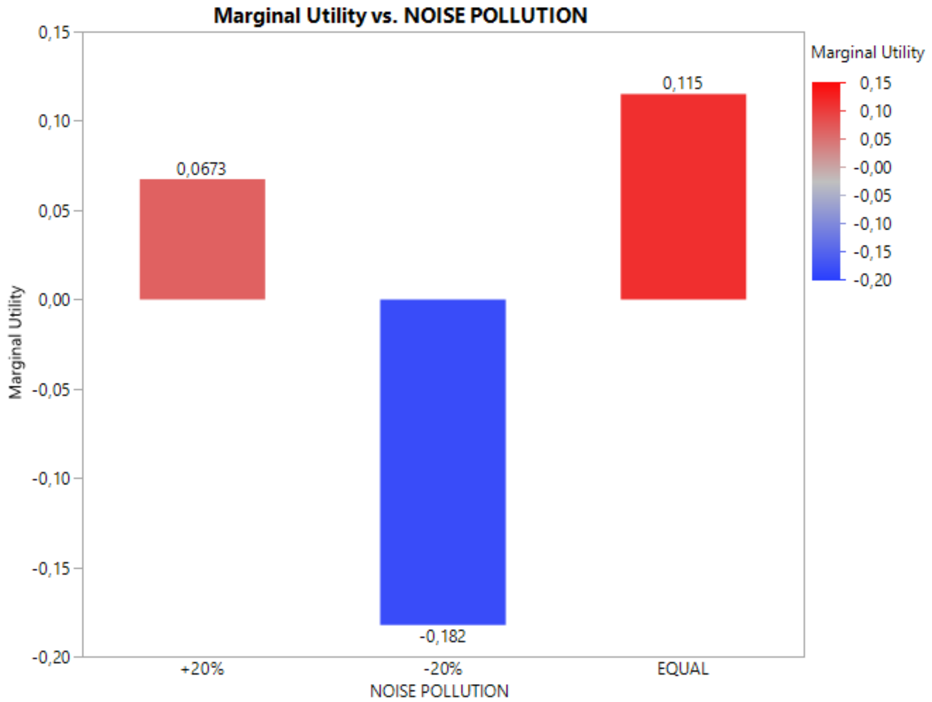

Figure Appendix 14.D *Marginal Utility Noise Pollution (Source: JMP)*

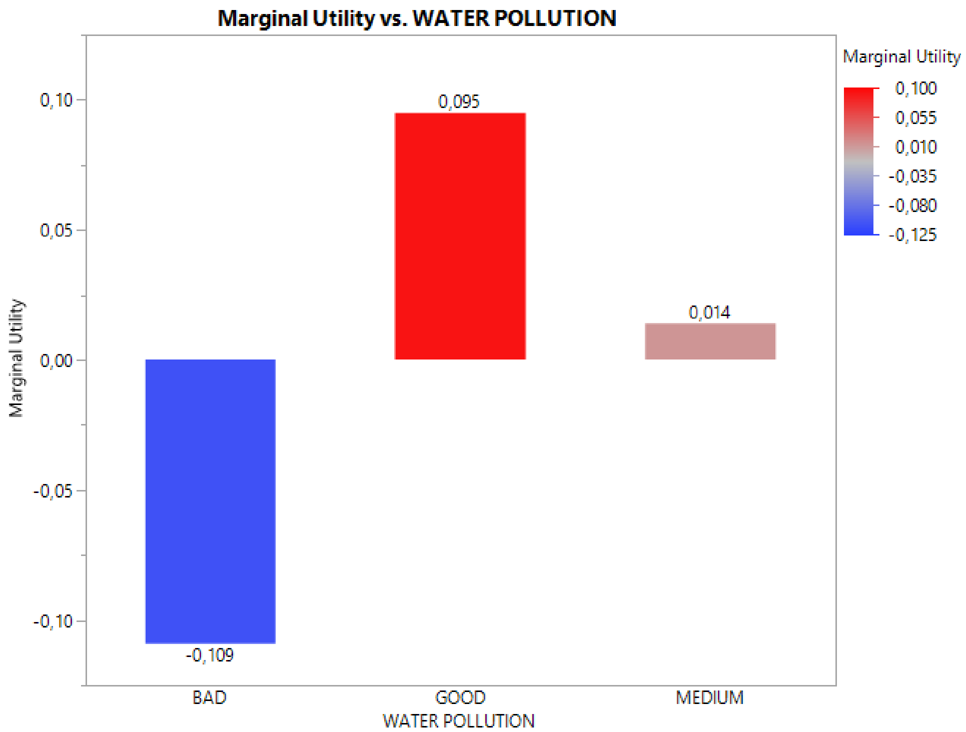

Figure Appendix 15.D *Marginal Utility Water Pollution (Source: JMP)*

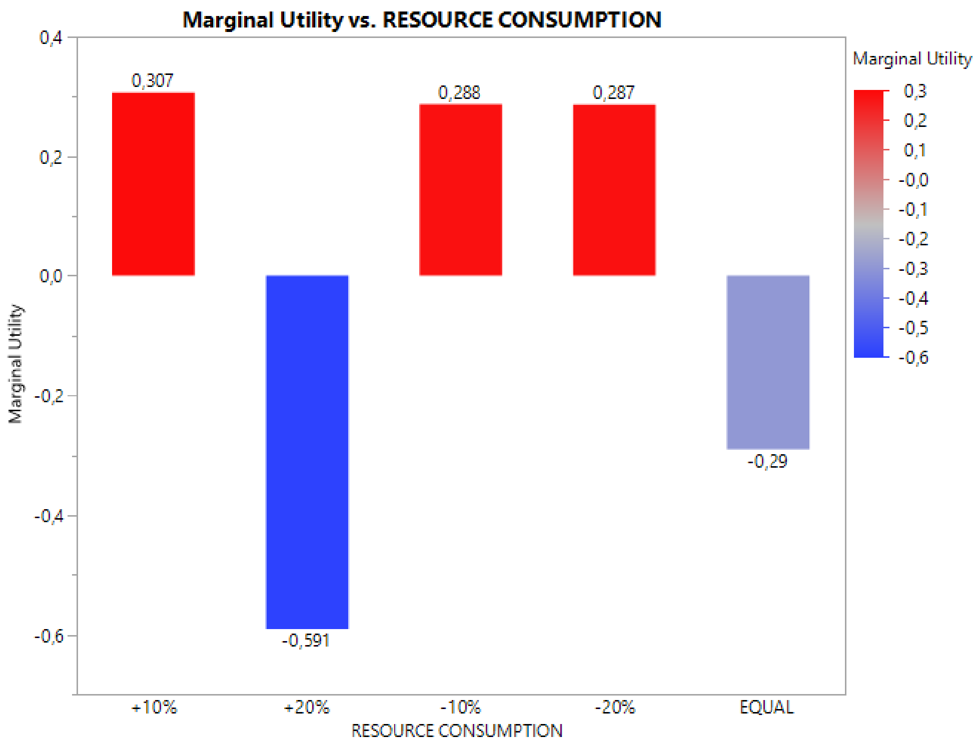

Figure Appendix 16.D *Marginal Utility Resource Consumption (Source: JMP)*

THANKS TO…

My parents

They have always been my strength. Source of support and courage.
They have always been close to me, especially in the most difficult moments.
I owe them everything. For better or for worse, what I am today, I owe them.

My brother

He is what I hold dearest in my life. I thank him of everything and for everything.
There is no smallest thing in my life that does not refer to him, that makes me think of him and for him.
Even if youngest than me, a great point of reference for me.
His way of being, talking, acting, thinking, so completely different from my ways, are the starting point, every time, for many of my discoveries about myself.
Though far away in so many moments of life, but so close and univocal in the streets.
Much of my world is also his. Good, affection, love for him are unattainable.

Alberto

He is in the innermost part of my heart.
He teaches me in the most profound way what strength is, what hope is, and what fidelity is.
He is more than a friend. He is more than a brother.
I have shared with him all these years behind the anxieties and fears of distance and study.
I shared with him all the ups and downs of our age and our lived moments.
As if it were a pivot in my life. Part of me turns around him. And I know that part of him turns around me. Even though, in recent years physically distant, always so close mentally and with the spirit; present in the support, in sharing, in words.
He is the only one able to listen also what I don’t say. Love for him is infinite.

Remo

He fills that part of me that doesn't exist.
Perhaps, the only one who has the ability to re-fill every space of my life.

I shared with him the most beautiful, joyful, most harmonious, most sensitive, happiest, most amusing and even the most complicated, hardest and most difficult moments of our journey in and out of the university.
Nothing was ever missing with him. A cry, a laugh, a word, a discussion, a hug.
It is as if in these years we had always held hands by accompanying each other on the path we have taken. With him, it is often a symbiosis of brain, eyes, hands, despite being so different in ideas and gestures. The sincerest years of my life, with him.
From him I learned, and I learn what it means to laugh in life and have a smile; think about the beauty you have and put aside the rest. I would never change him with anyone and love for him is not measured.

Andrea, Pina, Marco, Alessia, Domenico

They have been and will always be my part of carefree and my strong point.
If I go back in time, with them I have so many memories of these years that I could never remember them all.
They are the friends who most of all have shared growth with me. I have seen them become mature; they have seen me become mature.
With our joys, our satisfactions, with our half moments and also with our defeats.
With many of them, we were children when we met, and now we are still here.
I don't think there can be something sweeter and more beautiful than this.
Everyone has something it would never give up, and for me it is them. For nothing in the world.
Now I look at this moment and I see us adult. Everyone with own problems, each with own lives, each with different paths, each with own experiences. But still one in the other's life. Still here.
I'm sure I will never lose them. The close ties over the years have now become indissoluble.
I shared everything with them. They know the most intimate parts of me. They know how to take me, they know how to treat me, they know who I am in every way.
I will never end to say thanks to them.

Mara

She is the person who has been closest to me in recent years. She doesn't have many words, she doesn't have many thoughts, but she makes herself understood only with her eyes.

Her advices, her hints, her support have not been taken for granted, and in my difficulties her presence has never, ever been missed.

From her I learn what it means to be resolute, how to face life for what it is and for what it gives.

She, constant, smiling, willing, is something really very dear to me.

Maria

For me it's a special person.

She always had a special affection for me and me for her.

The love I want for her goes beyond so many things. What had created all that has been all experiences together; we have shared beautiful moments, carefree, light, serene, puzzling too.

She is perhaps the person with the most similar character to mine: that’s why we have understood each other many times. With her, few words, but right.

In her way of being, she was always present, attentive and available to me.

Really, thanks to you a hundred thousand times.

Edoardo

Giving space to a person like him was not so easy, but over time it has turned out to be a person who knows how to understand, who knows how to listen, who knows how to speak, who knows how to give you something of his own.

His way of being, although very particular, is now something that belongs to me too. I have to thank him because without any effort and in a very natural way it was a person who knew how to stay close to me in some moments.

I think he's a person from whom I learned so much, and I continue to learn, despite the fact that we don’t see so much each other. I love him a lot, even if not seems.

Dario

With him I shared the experiences of these most serious years.

He has been and will always be a valid support in many situations.

His being good, so kind, so strong, calm and serene at the same time, has taught me in these years to take things as they come, without too many problems and without having regrets.

To him I owe much of my goal.

He gave me moments that I won't be able to forget.

Renato

With him a few moments in these years, but the affection, love and brotherhood that binds me to him go beyond any obstacle.

He there has always been, and I will always thank him for it. I wear it on my skin.

He doesn't need too many words. His person, his kindness, is something really rare.

What binds us is very strong and never makes us forget where we came from.

He is a kind of intimate guide in my life.

I will never lose it.

To all my friend

Big thanks go to all my friends, those who in one way or another have always had a thought for me; to some of them I am bound by a truly unconditional and deep affection.

I know some of them since we were children, others have joined the path of my life.

With some of them the roads split early, but contacts have never been lacking and at times the mere fact of hearing them has given me strength and conviction.

For and with each one of them there would be something to express that portrays them and brings them back into my life, but since they would be too many, I just say that, with the same blood group of my soul, they are a great transfusion of happiness for me.