Environmental sustainability and climate change effects: an investigation into ports' response and readiness

by

Jimena Haza Vidal

Supervisor: Khalid Bichou

A dissertation submitted in partial fulfilment of the Degree of MSc. in Maritime Operations and Management.

City University London

School of Engineering and Mathematical Science

June 2010

DECLARATION

I certify that the dissertation that I have submitted is my own unaided work, and that I have read and complied with the guidelines on plagiarism as set out in the student handbook.

I understand that the University may make use of plagiarism detection software and that my work may therefore be stored on a database which is accessible to other users of the same software. I certify that the word count declared is correct.

_____ **Student**
Jimena Haza Vidal

_____ **Supervisor**
Khalid Bichou

Date: June 2010

Abstract

The increase in trade and economies of scale has influenced ports in respect to the growth and services they provide. Ports as trade commercial centres, in which international markets and national economies meet, must start considering how the impacts of extreme climate change influence their port management and operations. This particular study focuses on extreme changes in climate that may affect the development, operations and infrastructure of ports. In particular, research has been done into sustainable mitigation plans that have been implemented by port authorities in relation to GHG emissions, energy consumption, fuel consumption, sea level rise and extreme weather protection and ice coverage, with the goal to analyse the potential environmental adaptability of ports operations to climate change effects.

This study was based on a survey and case studies that provided primary and secondary data for the development of a comparative analysis among 10 different ports. The information gathered identified the range of measures and policies that ports are developing with a view to responding to climate change impacts. The study also uses Multi-Criteria Analysis to examine the degree of integration and adaptability of ports to climate change challenges, and the positive externalities such adaptations can bring to ports.

In general 40% of the ports investigated in this project have implemented not only GHG emissions and energy and fuel consumption mitigation plans but have also conducted research into the vulnerability of the port to sea level rise and extreme weather. The MCA results indicate that it is important for ports to start considering climate change impacts and developing sustainable mitigation and adaptation plans for their port operations in order to bring benefits to the port and the surrounding areas.

This project is part of an Erasmus Mundus International Masters Programme in Coastal and Marine Engineering and Management (CoMEM). This programme is integrated by five universities, Delft University of Technology (TUDelft), Norwegian University of Science and Technology (NTNU), City University London, University of Southampton (SOTON) and Catalunya University of Technology (UPC) with the aim to allow students to gather global knowledge and experience in this field.

Acknowledgments

Thanks to CoMEM and all the people involved in organising and putting together this program, TU Delft, NTNU, City University, SOTON and UPC.

Thanks to my advisor Khalid Bichou for his knowledge and guidance in the process of this project.

Thanks to all my Comemers colleagues. Thanks to Sarah, Badri, Mahtab, Anna, Danyl, Claudia, Claudio and Jose, for their friendship and fun times. Want to thank specially Sarah for her unconditional friendship, support and sharing with me these two amazing years of adventure and fun.

To my Mom for being always next to me. For teaching me and sharing with me all her experience and knowledge.

To my brothers, Roberto and Eduardo, my sisters in law, Leslie and Vanessa and my two little nephews, Max and Mariano, for their support and strength.

To my friends in Mexico, Sonia, Moni, Karla, Karen, Lore, Paola, Leo, Chabe, Carla and Mena for their group hug's and their unconditional boost of friendship doses.

Table of contents

List of Tables

List of Figures

Table of abbreviations

AAPA	American Association of Port Authorities
AENOR	Asociación Española de Normalización y CertificaciónSpanish Association for Standardisation and Certification
AIVP	Association Internationale Villes et Ports
AQMD	South Coast Air Quality Management District
CAAP	San Pedro Bay Ports Clean Air Action Plan
CAP	Climate Action Plan
CAPA	California Association of Port Authorities
CARB	California Air Resources Board
CHE	Cargo handling equipment
CNG	Compressed natural gas
CO_2	Carbon dioxide
ECE	Economic Commission for Europe (UN)
EMIS	Environmental Management Information System
EMS	Environmental Management System
EPA	Environmental Protection Agency
ESPO	European Sea Ports Organisation
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
GHG	Greenhouse Gas emissions
HC	Harbour Craft
HDV	Heavy-Duty Vehicles/trucks
IACP	International Association Cities and Ports
IAPH	International Association of Ports and Harbours
ILO	International Labour Organization
IMO	International Maritime Organization
IPCC	Intergovernmental Panel of Climate Change
ISO	International Organization for Standardization
ISPS	International Ship & Port Facility Security
MCA	Multi-Criteria Analysis
MEPC	Marine Environmental Protection Committee
nm	Nautical Miles
NOX-	Nitrogen Oxide
OGV	Ocean-Going Vessels
PANYNJ	Port Authority of New York and New Jersey
PERS	Port Environmental Review System
PIANC	The World Association for Waterborne Transport Infrastructure
PM10-	Particles measuring 10µm or less
POF	Port of Felixstowe
POLA	Port of Los Angeles
POLB	Port of Long Beach
POR	Port of Rotterdam
PSC	Port State Control

RCI	Rotterdam Climate Initiative
RETE	International Association for port-town collaboration
RL	Railroad Locomotives
RTG:	Rubber-Tyred Gantry cranes
SMDG-PROTECT	Message support programme used between shipping lines and/or their agents as well as Port Authorities and National Competent Authorities.
TEU	Twenty-foot equivalent unit
UKCIP	United Kingdom Climate Impacts Programme
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
WPCI	World Port Climate Initiative

CHAPTER 1

Introduction, Approach and Limitations

1.1. Introduction

Effective sustainable adaptation to manage risks posed by a changing climate is important in the present day. It is known that port cities will face issues in adapting to climate change impacts and that by 2070 these cities will be affected by flooding due to storm surge (Nicholls *et al*, 2007). This is why ports as trade commercial centres should now be considering the extreme climate change impacts that could occur and the influence they could have on port management and operations.

Ports are the points where international markets and national economies meet. Therefore the governments have the challenge to integrate the social and economic development of their countries while adequately managing the international trade and technological developments (UNCTAD, 1996). This evolution has also provided awareness about environmental impacts and a change in attitude towards climate change issues in relation to port activities and operations. Therefore the introduction of sustainable development has become a key topic for new growth in ports (Bichou, 2009).

Today, several organizations, associations, and port agencies around the world, such as the International Maritime Organization (IMO), the Environmental Protection Agency (EPA), the American Association of Port Authorities (AAPA), the International Association of Ports and Cities - Association Internationale Villes et Ports- (AIVP), the California Association of Port Authorities (CAPA), and the International Association of Ports and Harbours (IAPH), among others, have introduced a raft of legal instruments, policies and strategies in order to regulate environmental management of ports and provide adequate measures to avoid the adverse impacts of climate change and further marine environmental degradation.

Ports as the key nodes for other transport modes and trades have to consider the impacts that climate change can have on them and create the

necessary adaptation. In the context of this study, adaptation is defined as the action or actions of taking the adequate measures in order to avoid or minimise negative effects (UNCTAD, 2008). Such adaptation aims to understand the impacts of climate change and decrease the risk that climate change can cause to the port infrastructure and its operations. Therefore, an adequate management practice, planning activities, operations and specifications on design have to be re-evaluated. All these include planning and investment decision making into sustainable design and development (UNCTAD, 2008).

For the purpose of this project, we restrict the discussion of climate change to the extreme changes in climate that may affect the development, operations and infrastructure management of ports. These include but not limited to issues such as Greenhouse gas (GHG) emissions, energy consumption, fuel consumption, sea level rise and extreme weather protection and ice coverage.

1.2. Study Approach and Aims

The understanding of climate change and the impacts that these changes can create in ports is essential in order to offer the services that clients require (UKCIP, 2010). Furthermore sharing of information between the government, industry and communities allows these measures to be implemented in a coordinated and successful way.

The majority of ports are not preparing for predicted future climate changes. On one hand there are ports that have not even considered these impacts and in the other there are ports that do not see a significant risk to their operations and infrastructure (ICF International, 2008). Therefore the goal of this project is to analyse the potential environmental adaptability of ports operations to climate change effects. This will assist ports in understanding the importance of considering these impacts in their port operations and will allow the decision makers to understand the meaning of implementing these sustainable types of plans. Another aim is to generate a comparative analysis in order to understand the methodology and the present

position of ports in relation to these issues. The identification of the types of adaptabilities in port operations that are occurring at present and the analysis of the benefits and externalities of such adaptabilities are also investigated as the third aim of the project. The use of surveys and case studies will generate the data necessary to achieve the stated aims and the Multi-Criteria Analysis (MCA) aims to demonstrate to other ports that the integration and adaptability of ports operations to climate change impacts should be considered in ports all over the world.

1.3. Scope and Limitations

The current project attempts to systemically approach, analyse, and present, the subject of port operations and management in regards to the adaptability to climate change effects.

It is known that climate variability is happening today and that ports have to be prepared to reduce the risks of wetter winters, higher sea levels, stormy conditions, temperature rise and GHG effects on operations, health and safety of the port and surrounding areas (UKCIP, 2010).

The adaptation and development of ports at the present time are influenced by the economies of scale. Initiating new development plans for the growth of ports and ships are required as the international trade grows every day. Therefore the importance and need to consider the impacts of climate change to these new developments will benefit the ports to become a better competence against others.

The limitations of this project involve practical and theoretical issues as well as in respect to the research design and methodology. The following limitations are recognized within this project:

- This project is only focused on GHG emissions, energy and fuel consumption, sea level rise and extreme weather adaptation. But it is important to mention that port operations also include activities like allocation of cargo, storage, packaging, management of the vehicle

bookings, the delivery and receipt of cargo from landside and the allocation of yard space among others, that in this project are not considered;

- Time and word count limitations from the requirements of the university;
- Disadvantage of the low response to surveys and therefore results with indicating generalizations;
- Limitations on different types of data available in respect climate change impacts mitigation plans in the selected ports (ICF International, 2008); and
- Limitations on the validation and generalization of the outcomes of the research.

1.4. Outline of Project Content

This introduction has detailed the issues, importance and aims of this project. The background knowledge, theoretical concepts, and approaches relevant to the study which focus on the analysis of the adaptability of port operations to climate change impacts can be seen in Chapter 2. This chapter provides the literature review on ports operations and activities and regulation framework and presents the background related to environmental management, climate change impacts and port operations mitigations plans.

The methods used and applied in this project are stated in Chapter 3. The multi-approach is explained which considers the surveys, the case study method and the MCA. The procedures for the selection of the ports and the responses to the surveys are presented. The details of a MCA method are stated as well as the process in which it was developed.

The primary and secondary data of the ports is presented in Chapter 4. Firstly, information on the surveys e-mailed to the ports is given. After this, the information related to the secondary data of the five selected ports is presented. An analysis of these two types of data is also offered in this chapter as well as the detailed discussions of them.

The fifth chapter presents a MCA for the non-monetary evaluation of three alternative solutions proposed to adapt port operations to climate change. The three options include a zero-option alternative, the second alternative to implement GHG emissions and energy and fuel efficiency, and

the third option, which involves the adaptability to all climate change impacts. This method was used to select the best sustainable option in regards to a number of previously set objectives including social, economical, financial and environmental criteria.

The conclusions and recommendations chapter is a culmination of the background, assumptions, limitations, methods, results and analysis from this study that contribute to the understanding on the climate change effects and how the implementation and adaptation of sustainable mitigations plans is important for ports operations and management.

CHAPTER 2

Literature Review

Nowadays ports have become not only the point of exchange of cargo, but also they are the connection of logistics chains in which a flow of commodities and goods happens. The economic potential of ports provides advantages to the governments and therefore the port authorities and the government have to work together in order to adopt the more suitable port policies (UNCTAD, 1996). UNCTAD (1996) states that in order to get an adequate operation and financial performance in ports, ports' management needs to be flexible, independent, pro-active and accountable.

In this section the explanation of what a port is, its activities and operations as well as the regulatory framework and some of the mechanisms for environmental compliance are presented in order to understand how the port operations work and their relation to the environment. In particular, the author examines the theoretical background in respect environmental management and climate change initiatives. This will provide the tools for this project to understand what have been done and what else may be done ahead in respect to sustainable adaptability of climate change impacts in port operations and management.

2.1 Port types and roles

Ports are considered to be important centres for commercial trade, in which seaports, inland ports and hinterland connection are integrated in order to function as a whole.

The seaports are defined to be the central node areas with berthing or anchoring facilities for ships with the services and equipment for the inter-modal transport network to transfer goods from sea-land to ship-rail (Alderton, 2005; Bichou, 2009).

The inland ports or dry ports are considered to be the landside area of the ports with the hinterlands and forelands as part of them. They are the logistic centres in which cargo operations and facilities are offered; therefore, they are considered to be distributions centres. (Bichou, 2009; Alderton, 1995).

The different classifications of types of ports around the world can be considered depending on its functions (i.e. ferry, oil, container or cruise port), geographic scope (i.e. coastal, tidal estuaries or rivers ports), logistic status (i.e. feeder or hub port) or trade type (i.e. import or export port) (Alderton, 2005; Bichou, 2009).

Bichou, (2009) states that there are three methods in which activities and operations at ports have been studied. These approaches are the 1) economic; 2) engineering/operations; and 3) logistics and supply chain management (SCM) approach. The three methods consider the environmental management of ports that involve activities and services such as pilotage, mooring, planning, handling of cargo and storage, inventory management, port design, reliability, interoperability, performance measurement, purchasing and logistics functions optimisation among others.

In particular the economic approach study the international trade development in which the economies of scale and scope influence the amount of cargo and vessels managed at the port. Trade influences how the network structure manages its efficiency and its reduction in traffic. Also follows environmental regulations, initiatives and guidelines that organisations like the International Maritime Organization (IMO), American Association of Port Authorities (AAPA) and European Sea Ports Organisation (ESPO) have developed in order to improve safety and health as well as the positive and negative externalities and wider effects on the port operation and development (Bichou, 2009).

2.2 Ports Operations and Activities

Based on their classification, the type of services and planning that a port can offer are: ports work as sea-land access; berthing for ships; connection within intermodal transportation; industrial management; logistics centres;

environmental control and management of dangerous cargo; security and safety on the port; immigration for customs control; pilotage, mooring and tugging activities; loading/unloading, storage and distribution; repairs; and shipping services from agents, brokers, charterers and industries (Alderton, 2005).

The operational port planning involves two components, the procedure on how the information has to be managed and how the allocation of the resources needs to be done. An efficient operational port planning involves the integration and planning of three main areas, berth, yard and gate (Bichou, 2009). The berth planning is meant to increase efficiency at the terminal and optimise the time for loading/unloading and stowage. An important factor in the berth planning is the use of the vessels flag and the International Ship & Port Facility Security (ISPS) code certificates that provide the proof that the vessels comply with certain environmental regulations (Bichou, 2009).

The yard planning includes the transfer, staking and storage of the cargo within the yard. This planning in particular deals with the assignment of the yard handling equipment and labour, including the vehicles and the routes that need to be used. This corresponds to the type of vehicles, engines and equipment used to reduce any type of air and noise pollution (Bichou, 2009).

The gate planning is the management of the inland ports. In here, activities like vehicle bookings; delivery and receipt of cargo from landside; entry and exit of trains and trucks; and the configuration of the warehouse, platform and freight are managed. Due to the increase on efficiency on ports, reduction of congestion, the new approach of port-city interface and new security regulations, the gate planning is becoming an important issue to consider for the environmental management of ports operations (Bichou, 2009).

The monitoring of the operational port planning today enables the ports to measure the environmental quality and performance and reduce environmental risks. Doing this the port response and comply with the legislation and the stakeholders expectations. The selection of the adequate

monitoring tool depends on the type of port, type of activities and the requirements for each port. Tools like the Environmental Management System (EMS) and the Environmental Management Information System (EMIS) not only enable ports to determine if they are complying with the legislation but also facilitate the share of information and solutions in technical, managerial and legal aspects (Wooldridge *et al*, 2004; Bichou, 2009).

Another approach has been developed with the creation of national, regional and international organisations that aim at supporting the environmental management in ports as well as the share of information. Some examples are:

National Level

- United States Environmental Protection Agency (EPA) that aims to research and monitor, set standards and enforce activities to enhance and protect the environment and human health (EPA, 2009; EPA 2010c);
- Maritime Administration (MARAD) that is the agency within the Department of Transportation in the US that deals with issues that involve, ships and shipping, port and ships operations, environment, security and safety (MARAD: About us); and
- Ports Australia (2010) that represents the marine and port authorities in Australia providing the leadership and support in areas of interest.

Regional level

- EcoPorts that asses and improve the environmental performance of seaports and terminals, with the main goal to create and stimulate port sustainable management behaviour not only in the port operations and port development but also in the logistics chain (EcoPorts, 2006a; EcoPorts, 2006d);
- ESPO which has an Environmental Code of Practice that provides policies in respect safety standards, economic efficiency and environmental sustainability that influence the development of the European Ports (EcoPorts, 2006b; ESPO, 2010);
- AAPA which aims at serving the public ports by improving port management and operations, to support and put into practice

governmental policies, promoting the share of information and the creation of relationships, as well as public awareness of the roles and economic values of ports in the global transport system (AAPA, 2009a); and

- The California Association of Port Authorities (CAPA) that provides education in transportation, trade and the environment in relation to port operations as well as monitoring proposals regarding legislative and regulatory framework for the community (CAPA: About CAPA);

International level

- IMO that as mention before is in charge of developing conventions for maritime law such as safety issues, rescue, life saving appliances, fishing ships safety, load lines, flag state implementation, oil pollution (Stopford, 2009);
- Association Internationale Villes et Ports (AIVP) (International Association Cities and Ports (IACP)), aims to build contacts between the cities and their ports, creating an international exchange of knowledge and experience as well as showing the projects and achievements that port and cities have accomplished (AIVP, 2010b; IACP, 2010); and
- The International Association of Ports and Harbours (IAPH) that aims at creating relationships and co-operation among harbours and ports in order to exchange knowledge, experience and information about port management and operations promoting world peace and welfare of mankind (IAPH, 2006a);

2.3 Environmental Management of Ports

Environmental management of ports considers the activities and operation functions to get the standards needed for environmental protection and therefore sustainable development. The Port Authority has a dynamic role as an environmental manager and such management requires scientific-based research to support decision-making, identification of key-indicators for the achievement of the goal, and constant monitoring to asses the efficiency management and the environmental quality (Wooldridge *et al*, 2004; Bichou, 2009).

Since 1970's a change in attitude towards the environment on how to manage port activities has been developed. At this time policies in which environmental conditions were monitored for the health and safety of the workers were created. In these policies the impacts that port operations were having on the environment were not important. It was until the 1980's that policies for waste management and environmental impact assessment were developed (MARPOL 73/78); and in the 1990's the first initiative for monitoring environmental issues on ports was produced with the aim to understand the environmental aspects of port activities and operations, as well as their relation with habitats in the coastal environment (Wooldridge *et al*, 2004).

Bichou (2009) states four main port operations that have an impact on the environment. These factors include construction and dredging, land reclamation, ships and their navigation, and cargo handling and terminal operations (Table 2-1).

The interest in global environmental issues and the creation of an integrated port environmental management, provide the tools to tackle the environmental impacts, stated in Table 2-1. The consideration of environmentally friendly solutions for the logistic chains, new developments, infrastructures and transportation networks within the port operations will provide the adequate tools for a sustainable development (Wooldridge, C. et al. 2004).

Table 2-1. Four main Port operations and their environmental impacts.

Factor	Impacts
Dredging and construction	Coastal erosion; subsidence; lost of sediment; turbidity and degradation of water quality; change in morphology; change in physical aspects such as waves, tides and currents; degradation of fisheries and marine ecosystems; socio-economic changes.
Land reclamation (land use)	Loss of habitats; change in ecosystems; effects on flora and fauna; visual pollution; land use impacts;
Ships and their navigation	Water pollution; air pollution; noise and vibrations; aesthetic and visual pollution; contribution to climate change.
Cargo handling and terminal operations	Health and human injuries; air pollution, noise and vibration; degradation of surrounding areas; aesthetic and cultural impacts; land use changes, contribution to climate change.

2.3.1 Regulations in ports

It is important to consider the regulatory framework for environmental activities and geographical zones in ports that provide policies to regulate the global industry (Bichou, 2009). The United Nations Convention on the Law of the Sea 1982 (UNCLOS) (United Nations, 2010) shapes the board framework of maritime law and the IMO and the International Labour Organization (ILO), are the agencies in developing and maintaining international regulations for safety, security and the environment in order to standardise internationally the maritime law (Stopford, 2009).

These conventions have their own environmental management target and are integrated into the national law of the states that agreed to sign them (Stopford, 2009; Bichou, 2009). The Maritime Pollution Convention (Marpol 73/78); the Safety of Life at Sea (SOLAS); the London Convention and Protocol; the Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC90); the Convention for Safe Containers (CSC), 1972; the International Maritime Dangerous Goods Code (IMDG Code); the Code of Safe Practice for Cargo Stowage and Securing (CSS Code); and the International Ship Management (ISM) Code are some examples of these (IMO, 2002).

2.3.2 Mechanisms for environmental compliance

There are a number of national and regional initiatives and guidelines in ports. For example the Environmental Protection Agency (EPA) of the US has worked on over 20 legislations for port planning and operations (Bichou, 2009); or AAPA and ESPO are organisations that have created guidelines and initiatives for their regional sector.

Other guidelines such as the United Nations Framework Convention on Climate Change (INFCCC of FCCC), the UN/ECE/ILO/IMO guidelines for Packing of Cargo Transport Units (CTU), the IMO/UNEP Intergovernmental Panel on Climate Change (IPCC), IMO guidelines on the Provision of Adequate Reception Facilities in Ports, and the IAPH Guidelines on Port

Safety and Environmental Control are also being considered for environmental assessment and port operations and management (Bichou, 2009).

The Flag State Implementation and the Port State Control (PSC) are also considered when talking about regulatory frameworks in ports. The flag State is the legal authority under which any state may register the vessels creating a link between them (follow UNCLOS 1982). This flag state regulates all the commercial aspects, safety of operations and ship's labour laws such as taxes, company and financial laws, safety conventions, crewing and terms of employment and naval protection, and political acceptability (Stopford, 2009; IMO, 2002).

The PSC, also known as Coastal State, are organisations that aim the inspection of foreign ships in ports that have sign the Memoranda of Understanding (MoU) agreement, in order to check their conditions and equipment and verify that the management and operation comply with the international regulations (Stopford, 2009). These MoUs provide the existence of co-ordination among the ports visited and the ship on a regional basis, as they are signed for different ports in all the oceans around the world[1] (IMO, 2002; Stopford, 2009).

2.4 Climate Change and Port Operations

EPA (2010a) states that the terms climate change and global warming are used as synonyms but that climate change is more adequate because it does not only talk about the rise in temperatures but also about changes in wind, precipitation, amount of snow and cover of ice, and sea level rise that occur in an extended period of time. All of these changes are a result of natural or human factors/activities like changes in ocean circulation and changes in the intensity of the sun or by burning fossil fuels, deforestation and urbanisation.

[1] Europe and the North Atlantic: Paris MoU; Asia and the Pacific: Tokyo MoU; Latin America: Acuerdo de Viña del Mar; The Caribbean: Caribbean MoU; West and Central Africa: Abuja MoU; The Black Sea region: Black Sea MoU; The Mediterranean: Mediterranean MoU; The Indian Ocean: Indian Ocean MoU; The Persian/Arabian Gulf: Riyadh MoU.

UNCTAD (2008) states that climate change is a global challenge and that its main cause is the increase of concentration of GHG emissions in the atmosphere (IPCC, 2007; UNCTAD, 2008). An increase of GHG of 25% to 90% from 2000 to 2030 has being forecasted (IPCC, 2007). With this in hand, the IMO has created the Marine Environmental Protection Committee (MEPC) that aims at dealing with the international shipping GHG emissions (UNCTAD, 2008).

The OECD (2008) reports that the adaptations to climate change are a complementary response to the GHG emissions plans. These adaptations are based on actions that aim at reducing unfavourable consequences as well as to keep the beneficial opportunities.

In the case of the increase in temperature, it has been observed that in the last 100 years an increase on the average of earths surface temperature of 1.2° to 1.4°F (0.74°C) was presented (NOAA and NASA data in EPA, 2010b; IPCC, 2007). This increase of temperature can affect ports deteriorating the pavements, damaging the cranes and increasing energy consumption due to cooling technology systems (UNCTAD, 2008).

The global mean sea level has risen at an average rate of 1.8 mm/yr since 1961 and from 1993 this average rate increased to 3.1 mm/yr. This sea level rise is related to the local conditions of any area. They mention that this increase is due to the melting of ice, including glaciers, ice caps and polar ice sheets. Therefore the ice and snow extent has also being reduced in a rate of 2.7% per decade (IPCC, 2007). All these can have negative consequences on ports such as flooding, damage of terminals warehouses and storage areas and interruption of intermodal and hinterland connections and facilities (UNCTAD, 2008).

Change in patterns of winds and currents, and extreme weather like precipitation, storms, cyclones or hurricanes, heat-waves, flooding and droughts can disrupt the energy supply, the intermodal supply chain and transport connectivity; can bring water problems; and can produce changes in erosion and sedimentation patterns in and surround the harbours affecting the

access channels and increasing costs in dredging (UNCTAD, 2008; IPCC, 2007).

UNCTAD (2008) states that the impacts that climate change has in the maritime transport depends on the local conditions, design, policies and transportation systems. UNCTAD (2008) also mentions that there are some direct effects that have to do with the infrastructure, operations and maintenance and the indirect effects that are seen in the change of demand, change on trade, investment decisions, forestry and agriculture products, energy sources and fishing activities. Economically speaking the adaptation to these impacts has also an impact on the costs of any industry or country that adopt any type of measures to minimize these effects (OECD, 2008).

Optimisation of vehicles and supply chain, the use of IT sources of communications and intelligent transport as well as improve terminal access, reallocation of warehouses and storage to the inland ports, speed of upload/unload cargo, repacking, labelling, stuffing/unstuffing, weighing, reduction of congestion and provide onshore energy are some examples on what to consider to generate the adequate tools for the adequate sustainable mitigation and adaptation to climate change. (Alderton, 2005; UNCTAD, 2008).

In general, the integration and investment of new technologies that are environmentally friendly, the integration of alternative fuels and energy sources such as wind power or biofuels and operational measures like emergency evacuation procedures, transit management, monitoring procedures, are some of the potential mitigation measures against climate change that are recommended by UNCTAD (2008) for the maritime sector. The collaboration among port authorities, transport system, the logistic parties and the terminal operators is important in order to obtain port efficiency and positive results from the mitigation strategies (UNCTAD, 2008).

Until today it has being seen that some ports and organisations are already implementing national, regional and international initiatives,

programmes and strategies in order to adapt their operations to climate change impacts. Some examples are:

National initiatives

- The Clean ports USA was developed by EPA in order to facilitate ports to reduce emissions from the old engines that are used in their port operations today (EPA, Clean Ports USA, 2009a); and
- The ABPmer that developed a project to determine the risk, the implications, the opportunities and the business that the Associated British Ports (ABP) has related to climate change. They looked into sea level rise, increase in storms, temperature and rainfall (ABPmer, 2007).

Regional and International initiatives

- ESPO that supports projects under the global platform framework of the *World Port Climate Initiative* (WPCI) that was launched by the IAPH (IAPH, 2008).

Based on the literature review and theoretical background presented in this chapter, the author aims to analyse the environmental adaptability of ports operations to climate change effects such as sea level rise, increase in GHG emissions, energy and fuel consumption and extreme weather impacts. Investigation of sustainable initiatives, programmes and strategies in respect climate change impacts to port operations that today are being implemented in ports are presented. The next chapter offers a complete explanation of the methods and approaches applied.

CHAPTER 3

Research Approach and Methodology

An appropriate methodology is required in order to analyse the environmental adaptability of ports operations to climate change effects and to satisfy the main aim of the project. Another objective is to generate a comparative analysis of the primary and secondary data obtained from the different ports. A multi-approach has therefore been selected with a combination of the Survey method, the Case Study method and a MCA. The combination of the first two approaches generates the information needed to identify the types of sustainable adaptabilities in port operations. The MCA is conducted in order to recommend the implementation of sustainable mitigations and adaptations of climate change impacts to the port operations. In this chapter the Survey and Case study methods as well as the MCA are explained. The techniques used to gather the primary and secondary information as well as the MCA procedures are stated.

3.1 Primary data: Survey approach.

The surveys or questionnaires are based on a standardised technique used to ask a set of questions regarding the topic in concern to a group of people or sample. The surveys are used as descriptive tools to gather primary data about the population in question through a sample. This primary data is the information gathered directly from the source that in this case comes from the port authorities. Previous knowledge of the studied situation in order to know the sample size and the amount of data to be measured is required (Oppenheim, 1992; Atkin, 2010).

For this project a cross-sectional design survey was implemented in order to gather a snapshot of the situation today with a fair and representative sample. A simple and focused questionnaire, in both English and Spanish, with open and close questions was e-mailed to a number of different ports in the world to obtained the information needed (Appendix A).

The main advantages and disadvantages of this type of questionnaire that should be considered at any time of the project are (Oppenheim, 1992): Advantages: the data collection and the processing of each questionnaire has a low cost; avoidance of interviewer favouritism; and it has the ability to reach people living far away or abroad; and, Disadvantages: low response rates and consequent bad representation of the survey target population; unsuitable for people with poor literacy; no correction of misunderstandings, or any explanation; and incomplete questionnaires.

Selection of ports for the Survey

The selection of the ports was a combination between random ports and ports known that are important for the city. All the information in order to send the e-mails was obtained from the Lloyd's Register Fairplay Port and terminals Guide 2009-2010, as well as from the Internet web page from each port. The survey was sent to 48 different Ports via e-mail, although it was planned to be sent to 65 ports (Appendix B). These ports are located in Europe, America, Asia, Oceania and Africa. The survey was sent only to ports and not to terminals or organisations. This is because in general, they are the main authority responsible to start the implementation and mitigation plans for environmental impacts within the port.

3.2 Secondary data: Case Study method

The case study method is considered to be an exploratory study in which the selection of a single case or a small number of related cases, such as an individual, a group or an organization is used to obtain qualitative data. The data can be collected with methods like observations, interviews/surveys, documentary analysis, or through Internet web pages (Robson, 2002; Atkin, 2010). The method implemented in this work is within the studies of organizations and institutions (Robson, 2002) with the gathering of information through Internet web pages that provided the secondary data. This secondary data is considered to be the information that already exists in books, documents, reports, Internet web pages and films.

Selection of ports for the case studies and their Internet sources.

The selection of ports depended on the availability of data from the web pages of the ports. Web pages of different ports were navigated in order to obtain the information required to accomplish the objectives of this project. Mainly the selection and research of ports depended on the information available that is related to environmental issues, port operations and climate change. In specific programmes developed for the reduction, mitigation or adaptation to climate change effects such as the integration of new technologies that are environmentally friendly; integration of alternative fuels and energy sources such as wind power or biofuels; optimisation of vehicles; integration of a protective sea wall; reduction of congestion; and provision of onshore energy (UNCTAD, 2008; Alderton, 2005; ICF International, 2008).

3.3 Data Analysis

3.3.1 Primary and Secondary Data Analysis

The analysis provides a comparative analysis in relation to the primary data from the surveys and the secondary data from the case studies. The creation of five groups together with a differentiation on the size of the ports was developed in order to make this analysis more suitable with the objectives of the project. This analysis is presented in Section 4.3 and discussed in Section 4.4.

3.3.2 Multi-criteria evaluation method

The Multi-Criteria Evaluation method is a non-monetary method that is used to obtain a relative ranking of projects. The assignment of weights to different project criteria and then assessment of the different alternatives provides support to the decision maker in the final decision making process (Verhaeghe, 2007).

The MCA involves the decision maker that provides the information to an analyst in order to be evaluated. The information comes from a preliminary investigation that includes present and future costs as well as benefits to society. The generation of alternatives and the selection of different criteria to

obtain an adequate comparison of the project alternatives is the next step. For the final decision, appropriate weights are assigned to each criteria and the evaluation method applied. The results can also be used as feedback to improve the project alternatives. Figure 3-1 graphically demonstrates the MCA process used for the evaluation of projects.

This method was used in order to evaluate the mitigations and adaptations that the ports need to develop against climate change impacts in themselves. It was used to see the benefits and externalities that the implementation of sustainable alternatives can bring to the ports and the communities in the surrounding areas.

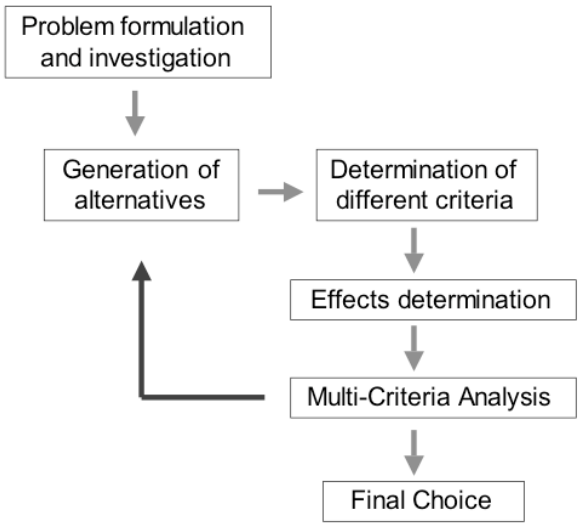

Figure 3-1. Process of Multi-Criteria Analysis.

In this project three scenarios were developed in order to compare and recommend to ports' authorities the adequate procedure to undertake climate change impacts. The first alternative is the "Do nothing" strategy. No change will happen to the port operations and infrastructure. The option 2 is based on implementing solutions for GHG emissions and electricity and fuel consumption; and the third option is the implementation of all the criteria that will contribute to the objectives of this project.

An appropriate assessment of the three alternative options and their designated scores is provided by the allocation of weights for the three criteria

categories in order to reach a total of 100%. The weights for the three criteria were allocated based on the perceived importance to the aims of this project, assigning values of 40% to the contribution to objectives, most crucial criteria to be fulfilled, and 30% to the impacts and resources criteria. It is important to mention that the assignment of the weighted values considered that every sub-criteria were of equal value to the category as a whole. Therefore, green inland port development, workforce and community safety and health, transportation network, new green source of energy and green buildings and infrastructure adaptation are considered to be equally important within the contribution to objectives category. Same pattern is followed for both the resources and impacts criteria categories.

The awarded value from the individual categories was then multiplied by the assigned weight value, following with the sum of the resulting values to obtain the final score (Table 5-4). The results of this evaluation are analysed in chapter 5.

3.4 Research Validity and Reliability

Due to the nature of the primary and secondary data that were obtained from the port authorities directly or through the Internet, the project has a certain reliability. The approach used in this project indicates the importance of ports in considering environmental management regarding climate change impacts. In some cases there are some organisational and operational differences that can result in difficulties when comparing the ports.

Through the selection and implementation of relevant research methods attempts are made to conduct valid research. The implementation of all three methods attempted to ensure that any information lacking from a certain port source was provided in another source to obtain a thorough analysis of the adaptation plans. However, further investigation on the research inquiry that can support the results of this project is recommended.

The next chapter provides the outcome of the methodological procedures. All of the information gathered form the surveys and case studies are presented as well as the data analysis and discussion.

CHAPTER 4

Data Collection, Analysis and Discussion

Earlier in this paper it has been mentioned that ships and their navigation, as well as cargo handling and terminal operations are two of the four factors in port operations that contribute to climate change impacts, in respect energy consumption and GHG emissions. There are also other climate change impacts like rise of sea level, increase in temperatures and increase in frequency of extreme weather, such as storms, hurricanes and flooding. The tackling of these climate risks would benefit any port in the world, situating the port in a better competitive sustainable level against others.

In this section the results of surveys as a primary data and the information from Internet web sites as a secondary data is stated. In particular, the secondary data is based on five case studies related to port operations and climate change. In some cases examples of terminal operators are given in order to understand their purposes in respect of climate change impacts.

It is important to note that for simplification, in occasions the name of the city in which the ports are located is being used. For example, instead of Port of Antwerp it is only necessary to mention Antwerp or for the Port of Singapore it is referred to only as Singapore. In the case of the port of New York and the Port of New Jersey, even when it is known that they are two ports they are considered as one port as the same port authority manages them and therefore PANYNJ is used.

4.1 Results from Primary Data: Surveys

Out of the selected 48 ports only 6 responded to the survey, corresponding to 12.5% of the entire sample. These six ports are: Port of Sydney, Port of Singapore, Port of Churchill, Port of Antwerp, Port of Gijón and Port of Greater Baton Rouge (Appendix C). The types of responses have varied, including the reply from Baton Rouge saying that *'climate change is a hoax'*. It is possible to identify ports that are developing adaptations to climate

change, or ports that have not even considered these issues yet. In the case of Singapore the information was obtained from PSA (2008).

Table 4-1 presents the results from the surveys received. This table shows port's awareness about the climate change impacts and if they are considering the impacts into new port developments. It also presents the impacts that are being considered for each port and what are the expected outcomes from these plans, as well as the associations/organisations to which they belong and if they follow any type of certification.

Table 4-1. Ports that responded to the survey**.**

Questions / Ports	Port of Sydney	Port of Singapore	Port of Churchill	Port of Antwerp	Port of Gijón
Aware of potential climate change impacts	Yes (they follow their *Sustainability Policy*)	Yes	Yes, year to year ice conditions.	Yes, aware of potential physical and economic impacts	Yes, eco-efficiency, energy efficiency, reduce CO_2 emissions
Major or minor developments in the port today	Yes Expansion of container handling facilities at Port Botany (Sydney Ports)	-	Yes Infrastructure improvements to the wharf face	No	Yes
Plan for future developments	Yes An Intermodal Logistics Centre at Enfield and a second Bulk Liquids Berth (BLB2) at Port Botany (Sydney Ports)	-	Yes, Plans to build bulk handling facilities	Yes New dock for container terminals (Saefthinge-dock)(time-frame >2020)	Yes Port extension, October 2010
Implemented environmental mitigation plans	None specifically implemented, only electricity consumption.	Yes Save energy campaign – electricity conservation	Any infrastructure improvements must go through an environmental approval process by the	Yes. Port has a clean air action plan: to reduce NOX- and PM10-emissions and –emission concentration. Mitigation	Yes. They follow the ISO 14001. In the last 4 years of implementation have seen reduction in the environmental

Questions / Ports	Port of Sydney	Port of Singapore	Port of Churchill	Port of Antwerp	Port of Gijón
			Government of Canada.	plans for other environmental issues.	impact on the port.
New port developments considering climate change impacts: Sea level rise, temperature increases, GHG emissions, extreme weather	Yes GHG and sea level rise	Yes Green energy: energy savings equipment (Quay Cranes, Yard Cranes and Prime movers), Fuel savings: RTGs, bio-fuels	No but they consider ice conditions and dissipation.	No concerns about climate change, but they focus on energy efficiency and renewable energy production.	No, but they have plans for reduction of GHG emissions.
Expected outcome of the plans	Electricity consumption reduction	2-50% of fuel savings depending on the RTG and the alternative fuel source used.	N/A	-	Air quality and energy consumption reduction
Port involved in any organisation such as ESPO, IAPH, AAPA, AIVP, EcoPorts or any other	IAPH, and Ports Australia	IAPH	Not aware	ESPO, IAPH and EcoPorts	ESPO, IAPH, AIVP, EcoPorts, RETE, SMDG-PROTECT and PIANC
Port involved in a programme or organisation/ certification	No	-	Not aware	No	Yes, ISO 14001 AENOR certification.
Cost/benefit analysis in regard to mitigation and adaptation plans	No	Percentage on fuel savings	No	No	No
- : Information not provided.					

4.2 Results from Secondary Data: five case studies

4.2.1. Port of Felixstowe

Port of Felixstow (POF) is the premier container port in the UK and it is operated by Hutchison Ports (UK).

In their efforts to know their contribution to climate change and the impacts that they may cause to the port, they have undertaken a climate risk assessment using the UKCIP Adaptation Wizard (UKCIP, 2010). They saw the risks of the port on weather changeability and climate change and determined the strategy to be followed. They explored the strength of the port infrastructure to future climate impacts. With all this they developed recommendations on how to mitigate and adapt to climate change and make the organisation aware of such impacts.

Regarding the CO_2 emissions, they have measured their carbon footprint. POF had shown a reduction in 2008 of 8.3% of their emissions of CO_2. In particular, POF has reduced their CO_2 emissions per TEU by 3.9% since 2008, indicating the improvement in their efficiency in container handling. These emission reductions have been generated from the implementation of more supply points to allow Rubber-Tyred Gantry cranes (RTGs) to be switched off when they are not used reducing fuel consumption. A reduction in speed in the RTGs engine when the cranes are not handling containers has been also implemented, resulting in a reduction of 25% on fuel consumption. In regard to the total energy use of the port, per 10,000 moves, a reduction of 3.8% has been noticed. For 2010, the port has joined the national campaign “10:10” to reduce 10% its GHGs emission (Port of Felixstowe, 2010).

The new development at the Felixstowe South Reconfiguration terminal project is going to be equipped by Siemens/ZPMC Eco-RTGs, which shall allow the port to save up to 50% of fuel consumption over the standard unit (Port of Felixstowe, 2010).

POF counts with the Port Environmental Review System (PERS) certification awarded by Lloyd's Register that can provide the tools to receive accreditation under ISO 140001; and is a member of IAPH, AIVP, EcoPorts and ESPO (AIVP, 2009; EcoPorts, 2006c; ESPO 2005).

4.2.2. Port of Rotterdam

The Port of Rotterdam (POR) expansion Maasvlakte 2, only accepts companies that are willing to operate their terminals in a sustainable manner. This takes into consideration air pollutants, sustainable energy and noise. With this they comply with the European environmental regulations and they take responsibility as Port Authority for the environment (Port Of Rotterdam, Maasvlakte 2). They have plans to tackle noise from trains and trucks using noise screens and quite road surface. Improving air quality with clean forms of transport, as well as working for cleaner water and implementing effective flood protection are also in their plans (Port of Rotterdam, 2004).

The POR is involved in the *Rotterdam Climate Initiative* (RCI), and its objective is to reduce CO_2 emissions by half by 2025. This reduction is compared to the emissions emitted in 1990 and involves a reduction of 30 million tonnes per annum. This task requires reducing energy consumption by 2% each year with the use of renewable energy. For example, in 2008 they created their first carbon footprint for the activities in 2007 based on the GHG emissions protocol from ISO 14064 that considers direct emissions (cars, own fleet and use gas heating buildings) (25%); indirect emissions (electricity use facilities, hired buildings and heat on buildings) (20%); and other indirect emissions (construction of quay walls, dredging, workers and commuting employees) (55%); and they are aiming at having a reduction of 35% on CO_2 emissions by 2012 (Port of Rotterdam, Annual Report 2008).

POR has also initiated the project Steam Pipe to become a CO_2 hub port. This involves the creation of the adequate infrastructure for the transport, capture and storage of CO_2. Trials until 2014 are taking place and from 2015 on there are plans for large scale implementation (Port of Rotterdam, Annual Report 2007). The transportation and storage of 5 millions tonnes of CO_2 per

year and 20 million tonnes CO_2 per year from 2025 (Port of Rotterdam, Jaarverslag 2008) on is planned.

The POR is part of the *IAPH World Port Climate Initiative (WPCI)*. This initiative has the mission to implement strategies and actions to reduce GHG emissions to improve air quality and provide the information on the effects of climate change on the ports environment and how this can be mitigated (IAPH, 2006b). POR is also member of EcoPorts (2006c), AIVP (2009) and ESPO (2005).

The APM terminal at the POR, has implemented a €12.5 millions Wind power network in its Maasvlakte container terminal. This network provides all the electricity for the terminal and aims at having a reduction of 45% a year in its CO_2 emissions (Fairplay, (2009); Green Port, 2009). The APM terminals are implementing innovative technology equipments such as Eco-RTGs, Hybrid Yard Trucks, Pavement Management System and Wind Power with the aim to reduce their CO_2 emissions globally by 15% per TEU handled (APM Terminals; Fairplay, 2009).

4.2.3. Ports of Long Beach and Port of Los Angeles

Since 2003, the port of Long Beach (POLB) has been working over the environment, and in 2004 they created the *Green Port Policy.* This policy undertakes, among others, the reduction of air emissions from the port activities and the implementation of sustainable development in marine terminal designs, development and operations with the use of renewable energies, biofuels and energy conservation (Long Beach Harbour Department, 2005).

The POLB works with the communities, offering a *Green Port Fest* every year. This gives the opportunity to the people to learn about the port operations, and environmental efforts to sustain the environment (The Port Of Long Beach, 2010a).

The CAAP is the *San Pedro Bay Ports Clean Air Action Plan* that was adopted in 2006 by the POLB and Port of Los Angeles (POLA) jointly with

EPA, California Air Resources Board (CARB) and South Coast Air Quality Management District (AQMD). Their objective is to cut pollution by 45% in 2012 from the five mobile sources used in port operations and activities, such as heavy-duty vehicles/trucks (HDV's), ocean-going vessels (OGV's), cargo handling equipment (CHE), harbour craft (HC) and railroad locomotives (RL). Within this plan the implementation of the *Clean Trucks Program* was executed and by February 2010 they had reached a reduction of 77% for POLB and 84% for POLA of their emissions produced by port related activities. In the case of POLB this initiative has already delivered big benefits to the quality of life of the community and has reduced public health risks (The Port Of Long Beach, 2010a, 2010b & 2010c). Today, both ports are working together for the updating of CAAP, to involve issues like a higher reduction on air pollution, new technology, better dockyards and cargo-handling equipment. Their budget for 2009-2013 is of US$194.5 million for POLA and US$256 million for POLB, plus the agencies funding (The Port Of Long Beach, 2010d).

For the fiscal year 2008-2009 POLB had approved a budget of US$440 million for investment on innovative air quality measures and for the *Green Port Policy* and CAAP environmental programs. New long-term developments such as Pier G and Middle Harbour had an assigned budget of US$800 millions and US$750 millions respectively. In the case of Pier G, US$8 million of these US$800 millions were allocated to the shore-power investment. This would allow the vessels to plug themselves to the shore and reduce their contribution to air pollution by 100% while they are in berth. In the case of the Middle Harbour new clean cargo-handling equipment will also be provided. Today, POLA counts on two containers berths that offer shore-power services (The Port Of Long Beach, 2010a).

The *Green Flag Program*, for POLB and POLA, allows the vessels to earn a green flag if they reduce their speed to 12 knots at 20 nm or 40nm from Point Fermin. This reduction on speed has contributed to the reduction of air pollution and therefore GHG emissions as by 2009, 90-95% of the vessels had reduced their speed at 20 nm, and 50-70% of the vessels had reduced

their speed at 40 nm. They are expecting to reduce the air pollution from 650 tonnes a year to more than 2,000 tonnes a year.

POLB has also invested in a new Hybrid tug technology with a value of US$8 million. It provides the benefits of reducing by 30% its fuel consumption and therefore reducing its contribution to air pollution in 44% (The Port Of Long Beach, 2010a).

In particular, POLA has the *Climate Action Plan (CAP)*. This plan aims at reducing the effects on climate change produced by port operations. Its objective is that by 2030 the emissions will be reduced by 35% below the 1990 levels. This will be achieved by using renewable energy, improving energy conservation and modifying land use and transportation patterns (The Port of Los Angeles, 2010a). Annual inventories of the air emissions and GHG emissions from vessels, the rail transit and truck transit at the terminals have been reported since 2006 in order to observe the development and expected success of the plan. For their 2008 annual inventory of GHG emissions, a percentage change reduction of -15% for OGV's; -2% for HC; -18% for CHE; -16% for HDV's; and -35% for RL from 2006 to 2008 has been observed (The Port of Los Angeles, 2010b).

POLA has a *Sustainability Plan* that includes CAAP and CAP as part of it. Under this plan, the port has planned its intention to develop a 10-megawatt photovoltaic solar system that will help to eliminate 17,000 metric tones of CO_2 a year. They already have a 1-megawatt photovoltaic solar system in its cruise terminal and it is aimed to be completed by 2013 (The Port of Los Angeles, 2010c).

It is important to note that POLB and POLA are also part of the *IAPH World Port Climate Initiative* as well as CAPA and AAPA (2009b).

4.2.4. Port Authority of New York and New Jersey (PANYNJ)

In general, the PANYNJ has developed programmes for reduction of GHG emissions, use of environmentally friendly vehicles, and construction practices. The port authority as part of the *Climate Change Adaptation Task*

Force is developing projections with the aim to reduce the risks that climate change impacts, such as sea-level rise and storm surge, can generate in their facilities and operations and develop the correct strategies to adapt and mitigate those impacts (ICF International, 2008; PANYNJ, 2010a).

In particular, there are three actors or areas that are implementing initiatives within the ports: Port Authority Initiatives, Tenant Initiatives and Port Regional Initiatives.

The Port Authority through the *Carbon Neutral Program* is trying to reduce their carbon footprint through investments in green vehicles, green constructions and application of measures to reduce electricity consumption. Today, most of the port authority's vehicles are *Green Vehicles* (PANYNJ 2010a). These are powered by compressed natural gas (CNG), E-85 ethanol, hybrid-electric or plug-in electric.

The port authority is also currently analysing data from their meteorological tower in order to know the wind productivity and determine if it is convenient to build a wind farm in the NJ Port facility (PANYNJ, 2010b).

In respect to the GHG emissions, they are buying carbon credits and getting renewable energy certificates. They are focused on implementing their *Clean Air Strategy,* a ten year strategy that had been adopted in November 2008. The aim is to reduce their emissions generated by the five mobile sources (OGV.s, HDV´s, CHE, CH and RL) used in port operations and activities regardless of the future growth of the port. They plan to reduce their GHG emissions by 5% each year in order to achieve a reduction of 80% from the 2006 levels by 2050 (PANYNJ, 2009a).

The tenant initiatives include the *Green Practices Task force*. These practices are voluntarily addressing among others, the air quality and energy conservation with the implementation of fuel conservation and the modernisation of cargo handling equipment. They have also implemented the *Green Ports Program* that includes the use of electrifying port cranes and unemployed locomotives in cold weather with the aim to reduce emissions (PANYNJ, 2009b).

The Port Regional Initiatives include the implementation of hybrid technology for yard hostlers in the NY Container Terminal at Howland Hook and APM terminal in Elizabeth. This technology aims at reducing and improving the fuel economy and its efficiency (PANYNJ, 2009c).

It is important to note that PANYNJ is part of AAPA (2009b).

In summary, we can see that these five ports have implemented and considered climate change impacts into their development plans. In particular, all of them have being focusing on GHG emissions and energy reduction, on implementing new sources of energy, the use of new clean transportation, and on implementing new green equipment. It is important to note that the POR, PANYNJ and POF have undertaken specific projections in order to observe the impact that sea level rise and extreme weather can produce on them.

The next section will analyse the results form the primary and secondary data in order to make a correlation among them and determine the trends in respect of this topic.

4.3 Analysis of Primary and Secondary data

From the information collected for the last two sections, an analysis of five groups of ports is provided (Table 4-2). These groups are: 1) Implemented climate change mitigation plans; 2) GHG emissions; 3) energy and fuel consumption; 4) Sea level rise and extreme weather protection; and 5) Ports involved in an organisation or certification. It can be seen that some of these groups overlap due to the direct effect that each of them have on one another.

The size of the port within these five groups depending on the ranking that AAPA (2009c) provided in its World Port Ranking 2008 is also considered (Table 4-3). Although it is known that most of the ports are ports that move millions of TEUs per year the classification was done as follows, ports that move less than 5,000,000 TEUs are considered to be small ports, and those that move more than 5,000,000 TEUs are large ports. Therefore, the large ports are Antwerp, Singapore, POLA, POLB, POR and PANYNJ; and the small ports are Churchill, Gijón, POF and Sydney. In the case for the ports of

Churchill and Gijón it was decided to consider them as small ports since they do not appear in the ranking list.

Table 4-2. Five groups classification for the analysis of the ports.

Ports /Groups	Implementation of climate change mitigation plans	GHG emissions	Energy and Fuel consumption	Protection against sea level rise and extreme weather	Port involved in an organisation and/or certification
Sydney	•	•	•	•	•
Churchill	•			•	
Antwerp	•	•	•		•
Singapore	•	•	•		•
Gijón	•	•	•		•
POF	•	•	•	•	•
POLB	•	•	•		•
POLA	•	•	•		•
POR	•	•	•	•	•
PANYNJ	•	•	•	•	•

Table 4-3. Small vs. Large Ports

Ports	Ranked in 2008	TEU's	Size of port
Sydney	67	1,783,794	Small
Antwerp	13	8,662,891	Large
Singapore	1	29,918,200	Large
POF	33	3,251,077	Small
POLA	16	7,849,985	Large
POLB	17	6,350,125	Large
POR	8	10,783,825	Large
PANYNJ	20	5,265,058	Large
Churchill	-	-	Small
Gijón	-	-	Small

Of the 10 ports considered in this analysis, only four of them are included in all of the groups, indicating that 40% of them are implementing strategies for sea level rise and extreme weather protection at the same time that they are implementing strategies for GHG emissions and fuel and energy consumption.

Group 1: Implementation of Climate change mitigation plans.

In this group all the 10 ports are included, indicating that they have implemented mitigation plans and/or are planning to implement them. Table

4-4 shows the plans implemented in respect the reduction of GHG emissions, energy consumption and sea level rise and flooding. It is important to mention that in some cases the proper names of the plans were not obtained.

In the case of the Port of Churchill and Antwerp, they were included in this group because even though they have responded that they are not considering mitigation plans and is not one of the biggest concerns, the former is measuring ice dissipation and the latter is implementing energy consumption efficiency and energy production.

It has been observed that both the small and the large ports are implementing adaptation and mitigation plans to its facilities, infrastructure and technology, showing no difference due to their size.

Table 4-4. Mitigation and adaptation plans.

Port	Plans
PANYNJ	*Climate Change Adaptation Task Force, Clean Air Strategy, Green Practices Task Force, Green Port Program*
POLA & POLB	*CAP, CAAP, Green Flag Program*
POLA	*Sustainability Plan*
POR	*Rotterdam Climate Initiative, Steam Pipe,* Flooding protection
Sydney	*Climate Change Risk Assessment,* Sea level rise adaptation
Singapore	Green Energy
Antwerp	Energy Efficiency and renewable energy production
POF	Sea level rise and GHG emissions
Gijón	GHG emissions
Churchill	Ice dissipation

Groups 2: GHG emissions

Ports of Sydney, Gijón, POF, POLA, POLB, POR, PANYNJ, Singapore and Antwerp are part of this group. Of these ports, the first three were classified as small ports and the remainder as large ports. However, no difference has been found in regards to these two categories as they have all demonstrated interest in implementing plans to adapt their operations and infrastructure to reduce GHG emissions.

The only information gathered in regards Port of Sydney and Gijón is that they are implementing GHG emissions reduction plans through eco-efficient and energy consumption projects.

Programmes for the reduction of emissions of the five different modes of transport, OGV.s, HDV´s, CHE, CH and RL, in the port operations and activities have being implemented. Example of this is the *Clean Air Strategy* and the *Clean Truck Program* (Table 4-5).

Other types of plans include the reduction of speed in ships, such as *CAP* and the *Green Flag Program*; by joining national campaigns, such as POF in the "10:10"; and/or by measuring their carbon footprint. In this last case, POF has analysed their operations for carbon footprint to obtain the CO_2 emissions (Table 4-5). They have seen reduction in their emissions due to the implementation of more supply points to allow RTGs cranes to be switched off when they are not in use.

Table 4-5. GHG emissions reductions in the ports.

Port	Emission reductions
POF	In 2008 – 8.3% on CO_2 emissions & 3.9% on CO_2 per TEU.
POR	By 2012, reduce CO_2 emissions by 35%; By 2025, reduce by CO_2 emissions by 50%; Storage and capture of 5 millions tonnes of CO_2 by 2015 and 20 millions of tonnes of CO_2 by 2025.
POLB	77% reduction in CO 2 emissions from the five mobile sources (*Clean Truck Program*); Hybrid Tug – reduction of 44% in air pollution.
POLA	84% reduction of CO2 emissions from the five mobile sources (*Clean Truck Program*); 35% reduction on CO2 emissions in *CAP*; Solar system – reduction of 17,000 mt of CO_2 per year (*Sustainability Plan*).
POLA & POLB	Reduce air pollution from 650 tonnes to 2000 tonnes per year (*Green Flag Program*).
PANYNJ	5% reduction in CO2 emissions from the five mobile sources to achieve a total reduction of 80% by 2025 (*Clean Air Strategy*).

In the case of POR the implementation of the Rotterdam Climate Initiative (RCI) to reduce their CO_2 emissions is in process. They follow the ISO 14064 for reduction of GHG emissions and they are also implementing the capture, transport and storage of CO_2 (Table 4-5). In particular the APM

terminal in this port is producing wind power reducing their CO_2 emissions by 45%.

There is no specific information about the port of Singapore and Antwerp in regards the implementation of GHG emissions plans. However, they have been considered to be in this group because they are focused on energy consumption efficiency, energy savings and fuel savings. Therefore, there is a direct reduction of the GHG emissions produced at the ports.

Group 3: Energy and Fuel Consumption

This group is formed by nine ports out of the sample of 10, Port of Churchill the only one which is not part of this category. The size of the ports does not result in difference in their implementation of energy consumption plans.

In this group, plans such as the *Sustainability Plan* (at POLA) to develop photovoltaic solar system; the use of renewable energy, improving energy conservation (at POLA); and the use of new Eco-RTGs and reduction in speed in the RGTs engine when not in use are being implemented (at POF). A reduction of fuel consumption of 50% and 25% for the Eco-RTG's and speed reduction strategy, respectively is expected.

In particular, the *Green Port Policy* (at POLB) is building a new long-term development in which the implementation of shore-power and new clean cargo-handling equipment is considered. This will allow the vessels to reduce by 100% their energy consumption and therefore their emissions produced, as well as to improve the efficiency of the cargo handling and reduced time at berth. The use of hybrid tugs (at POLB) allows to reducing fuel consumption by 30%.

The POR, through its *Rotterdam Climate Initiative (RCI)* is using renewable energy and aim to reduce their energy consumption by 2% per year. As mention before the APM terminal in this port is using a wind power network as well as Eco-RTGs and Hybrid Yard Trucks with the aim to reduce the energy and fuel consumption.

The *Carbon Nautral Program, in PANYNJ* has used green vehicles, green construction and reduction on electricity consumption. The green vehicles are powered by CNG, E-85 ethanol, hybrid-electric or plug-in electric. In this port, the processing of data for the wind productivity for the development of a wind farm in NJ Port facility is being analysed.

In cases such as the Port of Gijón, Sydney and Antwerp implementation of electricity consumption and energy savings has being developed and plans for the future to go further in issues related to energy consumption and renewable energy production are being considered.

The Port of Singapore is into the energy campaign for electricity conservation. They are implementing Green energy solutions for energy savings equipment such as quay cranes, yard cranes and prime movers, as well as fuel savings with the use of RTG's and bio-fuels expecting savings from 2% to 50%.

Group 4: Sea level rise and extreme weather protection

This group is conformed by Sydney, Churchill, POF, POR and PANYNJ. The first three have been considered as small ports and the last two as large ports. Again, it is seen that the size of the ports makes no difference in the implementation of sea level rise and extreme weather protection.

Table 4-6. Plans for protection against sea level rise and extreme weather.

Ports	Strategy
PANYNJ	*Climate Change Adaptation Task Force*: developing projections with the aim to reduce the risk that climate change effects can generate in their facilities and operations.
POF	Undertaken a climate risk assessment using the UKCIP Adaptation Wizard in order to obtain the potential impacts that change in weather can bring to the port and its operations.
Sydney	Considering the sea level rise and the mitigation to it when the measures are available and appropriate.
POR	In Maasvlakte 2 is considering the protection against flooding. It is also known that because the Netherlands is below the sea level, they have always been concerned about sea level rise and flooding.
Churchill	Ice dissipation measurements.

The port of Churchill, as in group one, has been considered in this group because of their efforts on measuring the ice dissipation through the years and the ice cover in the Hudson Bay and the Hudson Strait. Table 4-6 shows the strategies of each port.

Group 5: Ports involved in an organisation or certification

In this group, a pattern with respect to the organisations in which some of the ports are members is observed. In general, ports are members of an organisation that collaborates with the region of the continent to which they belong. For example POLB and POLA are part of the CAPA; POR, Antwerp, Gijón and POF collaborate with ESPO; Sydney is member of Ports Australia; POLB, PANYNJ and POLA are associated with AAPA; POR, Antwerp and Gijón are part of EcoPorts.

It has been observed that most of them are part of the international organisation IAPH (POLB, POLA, POR, Sydney, Singapore, Gijón and Antwerp); and in the case of POR and Gijón also are members of AIVP.

At present, some of the ports count on certifications like PERS, ISO 14064 and ISO 14001 Environmental Management System (EMS) certification. Other ports like Sydney, Antwerp and Churchill do not count with any of these certifications.

In this section it is also seen that there is no difference among the size of the ports in respect to the type of organisation they are with. Most of them belong or form part of an international, regional or national level organisation.

4.4 Discussion of the results

It is known that the ports operations and activities have been studied using different methods and that within the economic method the environmental regulations, as well as the externalities effect have been considered (Bichou, 2009).

The survey was used to collect primary data relevant to ports operations and climate change impacts. The surveys were e-mailed to relevant people

from the port authority, as they are the key agents in providing the adequate management on the port facilities (Bichou, 2009). Only 12.5% of responses were received. This indicates a low response from the ports that can be due to the lack of interest in the subject of inquiry. This low response is a disadvantage of the method that can lead to certain errors in the generalisation analysis (Oppenheim, 1992). One of the six ports that have responded to the survey, the port of Great Baton Rouge has responded to the survey with a statement saying, *"climate change is a hoax"*. This can possibly be because the person that responded to the e-mail did not wanted to respond, or that he does not believe in climate change. It is also possible that the Port of Baton Rouge is implementing environmental plans, but in order to confirm these possible facts, further investigation must be done.

In respect to the ports of Sydney, Gijón, Singapore, Antwerp and Churchill, it appears that they are aware of the climate change impacts and that all of them are implementing some sort of mitigation plan to one or more climate change impacts. In general, the climate change impacts that seemed to be tackled by Sydney, Gijón, Singapore and Antwerp ports are the reduction of GHG emissions and energy and fuel consumption. The use of new technologies, alternative fuels and energy sources are the strategies implemented by them and are also the solutions and adequate tools that UNCTAD (2008), Alderton, P.M. (2005) and the ICF International (2008) have suggested.

It was mentioned previously that the Port of Churchill is considered to be undergoing a climate change adaptation as they are measuring the ice coverage in the region. It was decided to include this port in the climate change mitigation plan group based on the EPA (2010a) statement that ice coverage is one of the impacts that a change in climate can produce. The research into ice dissipation is more likely due to the geographical location of the port and the potential consequences of ice coverage including flooding, damage to terminal warehouses and storage areas, and interruption of intermodal and hinterland connections and facilities (UNCTAD, 2008).

There were also responses that were not expected such as the Port of Sydney being a member of Ports Australia, or Gijón being a member of RETE, SMDG-PROTECT and PIANC. Another answer that was not totally accurate is that the Port of Antwerp is a member of the AIVP (2009), information that had not been stated in the survey.

In respect to the case studies, five cases were selected POLA, POLB, POR, POF and PANYNJ. The selection of these cases was based on the research previously done about the environmental plans implemented in port operations as well as because the information can be easily found through their Internet web pages. This is due to 1) the national and international regulations developed by agencies such as EPA and IMO, that ports have to follow in order to provide and make public all the information related to the research and environmental plans; and, 2) because the associations/organisations of which the ports are members allows the sharing of information and knowledge in order to enable other ports to implement strategies already proved as successful. The latter being organisations like EcoPorts (2006a), AIVP (2010b), AAPA (2009a), IAPH (2006a) and CAPA (CAPA: About CAPA) in which it was seen that nine of the 10 ports belong at least to one or more of them.

In general, it seems that the five case studies have been developing mitigation plans against climate change impacts. Implementing plans like *Green Port Program, Green Flag Program, CAAP, CAP, Carbon Neutral Progam, Sustainability Plan, Clean Air Strategy, Green Practices Task Force* and *Rotterdam Climate Initiative* in which reduction of emissions, fuel savings, speed reduction, energy savings, fuel consumption, new cargo-handling equipment, green vehicles and shore-power plugging are the main objectives.

It has also been shown that some of these strategies have already reduced the GHG emissions, and energy and fuel consumption at the ports with reductions like 3.8% of CO_2 emission in 2008 for POF; reducing by 44% air pollution by using hybrid tugs in POLB; and for the POLA form 2006 to 2008 a reduction on the five mobile sources was achieved with reduction numbers like -15% for OGV's; -2% for HC; -18% for CHE; -16% for HDV's;

and -35% for RL. This indicates that the programmes have been successful and the reason why they are still implementing new sustainable strategies.

Even though an analysis was conducted to compare large ports to small ports, there was no evidence that this difference in size caused a problem for them in implementing climate change mitigation and adaptation strategies. This can be because climate change impacts still have an affect on ports, independent of their size or the developments occurring in the ports.

It has been shown that 40% of the ports in the analysis comply with the implementation of strategies for sea level rise and extreme weather protection, GHG emissions, and fuel and energy consumption. This seems to be due to the acknowledgement of the risks that the port faces against sea level rise and extreme weather, and the vulnerability of the coast to storms and flooding (IPCC, 2007). It is also possible because they have the economic and scientific sources to develop such strategy. However, all the ports are at least part of one group indicating that the 10 ports investigated are, in a way, concerned about the environment and how the climate change impacts can influence and affect their port operations and management.

In the next chapter a MCA is presented. This MCA will consider the information gathered in this chapter to recommend the implementation of sustainable mitigation and adaptation plans to climate change effects to port operations, showing why it is important and the benefits that this may bring to the port and surrounding areas.

CHAPTER 5

Multi-Criteria Analysis.
Evaluation of alternatives for ports adaptation to climate change effects.

Based on the objectives of this project and using a MCA evaluation method, different criteria is going to be considered in order to assess the contributions of three alternatives in sustainable mitigation and adaptation of the ports operations to climate change effects. As mention in the methodology the three alternatives are: first alternative is the “Do nothing” strategy; option 2 is based on implementing solutions for GHG emissions and electricity and fuel consumption; and option 3 is the implementation of all the criteria that will contribute to the objectives of this project.

The following assessment includes social, environmental, financial and economic criteria that are based on the information gathered in the previous chapter. It is important to mention that this MCA is an example analysis that shows how the adaptation and mitigation of ports to climate change effects is important for any type of port in order to be prepared in providing good sustainable services and trade competency for the future as well as to bring positive externalities for the surrounding areas.

5.1 Evaluation criteria

Contributions to objectives

Green inland port development	Construction and reallocation of inland port facilities.
Workforce and community safety and health	Better environmental areas and air quality; positive externality for surroundings areas.
Transportation network	Connectivity among ports: Inland-seaport; increased transport inland-harbour; less congestion; positive externality for the community.
New green source of energy	New sources of energy; savings; use of biofuels, wind turbines, new modes of transport, shore power plug-in, new cargo-handling equipment.

Green Buildings and infrastructure adaptation	Against extreme storms and flooding; clean and green resources.
Impacts	
Sea level rise	Long term impact. Negative effects in port operations, services and buildings in the port.
Air quality, GHG emissions	Short and long term impact; vehicle emissions; air quality affected by increase in shipping activity and land based transport; negative externality for the community.
Noise pollution	Short and long term impact; result from construction/adaptation activities; increased shipping activity and land-based transport; negative externality affecting the surrounding areas.
Traffic	Short and long term impact increase in port activities; increase in the number of vehicles in the area; increased shipping activity and land-based transport; negative externality affecting the surrounding areas.
Flooding (extreme weather)	Affecting machinery and equipment used in port operations and in port infrastructure.
Resource use	
Investment costs	Initial costs invested in the adaptation and mitigation of the port operations.
Maintenance	Costs involved in the maintenance of the port operations adaptabilities.
Revenue due to better competency	The amount of income generated by national/international trade. Enhanced competency compared to other ports, providing more income for terminals that are better prepared to climate change effects; positive externality for the community.

5.2 Weighting of alternatives

The assessments of each alternative with regard to the different evaluation categories is presented in Tables 5-1, 5-2 and 5-3, and are scored in the scales given below the tables. Table 5-4 present the final results calculated. In

the methodology, an explanation of the assigned weights for each category is provided. Sections 5.3 and 5.4 discussed the analysis and conclusion of the alternatives.

Table 5-1. Contribution to objectives criteria for the analysis of the three alternatives.

Alternatives	Contribution to Objectives				
	Green Inland port development	Workforce and community safety and health	Transportation network	New green source of energy	Green Buildings and infrastructure adaptation
1	0	-	-	--	0
2	+	+	+	++	++
3	++	+	+	++	++
(-- = very bad; - = bad; 0 = neutral; + = good; ++ very good)					

Table 5-2. Impact criteria used for the analysis of the three alternatives.

Alternatives	Impacts				
	Sea level rise	Air quality, GHGs	Noise pollution	Traffic	Flooding
1	0	--	-	-	--
2	0	++	+	+	--
3	0	++	+	+	0
(-- = very bad; - = bad; 0 = neutral; + = good; ++ very good)					

Table 5-3. Resource use criteria for the analysis of the three alternatives.

Alternatives	Resources use		
	Investment costs	Maintenance costs	Revenue
1	0	--	+
2	-	-	-
3	--	--	-
(-- = very high; - = high; 0 = neutral; + = low; ++ very low)			

Table 5-4. Final scores calculated based on the individual scores of each alternative for the three categories and the weighted values.

Criteria	Alternatives			
	1	2	3	Weights
Contribution to Objectives	-4	7	8	0.4
Impacts	-6	2	4	0.3
Resources Use	-1	-3	-5	0.3
Total	**-3.7**	**2.5**	**2.9**	

5.3 Analysis of alternatives

4.1.1 Option 1

The first alternative presented is in accordance with a 'Do nothing' strategy. In this zero option, the port operations continue the way they had always operated, not implementing sustainable mitigation and adaptation plans into the ports in regard to climate change impacts.

The scores were selected based on the information of the 10 ports early stated. In regard to the contribution to the objectives category, the green inland port development, and the green infrastructure and building development were rated as neutral. This rate was based on that no new developments or adaptations are going to take place in the ports. In the contrary, the transportation network, the workforce and community safety and health and the new green sources of energy are negative. The transportation network will not improved, bringing in the long-term negative externalities to the community in relation to the traffic and air pollution. The no investment on new green sources of energy would impact the air quality in the port and surroundings areas affecting the health and safety of the workforce and the community.

In regard to the impacts, the sea level rise is scored as neutral because of the minimal effect that this would have in general in the short term at the ports. This short term has been considered as the effect of sea level rise is a long term basis impact and ports authorities are not willing to make investment for this amount of time or even concerned about this issue. However, the air

quality and GHG emissions, noise pollution, traffic and flooding are going to affect the ports as it is expected that the trade, the use of non efficient equipment and extreme weather will magnify them. These impacts will also generate negative externalities like health problems, air and noise pollution as well as traffic to the communities around the ports.

In this zero option is important to mention that no investment costs are necessary and the revenue that can be obtained through better competency compared to other ports is being affected. In relation to the maintenance costs these will increase due to the negative impacts that the climate change will have in the port operations.

4.1.2 Option 2

The second alternative is based on what the majority of the ports have been done until today: Implementing solutions for GHG emissions and electricity and fuel consumption.

In this option the new green source of energy and green buildings and infrastructure adaptation were all highly ranked due to the increase in environmentally friendly solutions. These solutions include new sources of energy such as biofuels and the provision of shore power plug for the vessels reducing the emissions at berth. Until today, it has been seen that the implementation of these new sources of energy and the provision of new sources of modes of transport has produced efficient reduction of GHG emissions. This has a positive impact on the efficiency in the transportation network reducing traffic, and in the safety and health of the workforce and community in and around the ports.

This second alternative will also have positive benefits and externalities regarding the impacts category. In regards to air quality, GHG emissions, noise pollution and traffic that would be reduced by the implementation of environmentally friendly sources of energy. This will offer better quality of life with less noise, air pollution and traffic to the surrounding areas. The sea level rise is categorised as neutral as this will stay the same or would not affect the

port operations. However, in case of flooding, the port operations would have a negative impact as no new development has being implemented.

The investment costs associated with mitigation and adaptation to climate change effects in the port operations are higher compared to the zero option, but below the investment activities in the third option. This is mainly due to the costs of the new energy consumptions machinery and other plans to reduce GHG emissions. The maintenance costs have also been considered to be high but not as much as the third option. This option needs new vehicles, new equipment and new sources of energy and fuel. The revenue in this case will be positively affected as the investment on new infrastructure and equipment to correctly handle the climate change impacts will allow a better competence compared to other ports. This revenue will bring positive externalities to the community, bringing more trade and therefore more jobs and markets to them.

4.1.3 Option 3

The third alternative is the implementation of all the criteria from the contributions to the objectives category necessary to mitigate and adapt the port operations to GHG emissions, extreme weather (flooding), sea level rise and energy and fuel savings.

In this option the green inland port development, new green source of energy and green buildings and infrastructure adaptation were all highly ranked due to the increase in environmentally friendly development, providing new source of energy or shore power plug. Implementing environmentally friendly infrastructures and equipment in which the ports operations may be managed also have a positive influence in the GHG emissions and the energy consumption. The sustainable adaptation of buildings and infrastructure will also provide prevention to flooding. All of these will contribute to the safety of the workforce and community in the port and in the surroundings. The transportation network would improve due to the introduction of better connectivity routes on land and by sea, making the port operations more efficient, improving the logistics and reducing traffic.

This third option will also have positive benefits regarding the impacts category. These impacts would be positive affected, where the air quality, GHG emissions, noise pollution and traffic would improve due to the implementation of environmentally friendly sources of energy, more efficient port operations and better infrastructure and equipment that may handle extreme weather climate. The sea level rise and the flooding are categorised as neutral as there is no impact in port operations due to the improvements implemented.

However the investment costs associated with the implementation of mitigation and adaptation plans to climate change effects in the port operations are highly compared to the zero option and the second option. This is mainly due to the investments of millions of dollars. The maintenance costs are also considered to be high as all the adaptations will require to be maintained and have a certain quality level based on regulations and certifications. The revenue will be positively affected, as all the mitigation and implementation will put the ports in better positions in the future, bringing more money to the port. This will also provide positive externalities to the community, improving the market position, attracting more trade, and providing more jobs.

5.4 Conclusions of the MCA

In this chapter the analysis of a MCA is presented. The consideration of three different alternatives, zero option, option 2 and option 3, was analysed in order to offer a sustainable solution related to port operations in the integration, mitigation and adaptation to climate change.

The zero option with a final score of -3.7 indicates that is not advisable to be considered, and that the second and third option with scores of 2.5 and 2.9, respectively, are recommended for the implementation of solutions to climate change effects.

Option 1 ranked below the option 2 and 3 due to its lack of contribution to port operations and climate change effect objectives. There are negative impacts and externalities occurring as a result of no plans implemented. The

option 3 fulfils the great extent of objectives to implement and mitigate the climate change effects in port operations and management. It is important for ports that have not started thinking about the implementation of sustainable solutions should begin to do so. They have to start following the large and small ports that are already implementing these types of projects in order to be in the competency level to offer services and maintain their infrastructures in an adequate quality.

Option 2 although is only focused in GHG emissions and energy consumption efficiency is also a good option to be considered. This option is recommended when no sea level rise and flooding risk is presented in the ports, or when the ports do not have enough economic resource to implement such big investments. The analysis and projections on the situation of the port in respect sea level rise and extreme weather is recommended in order to determine the risks that the port will have in the future in respect these issues.

In general, the assessment of the above mentioned factors and by comparative analysis of the three alternative options, the zero option was excluded as an option for port operations adaptation. It is recommended that ports shall start considering the effects of climate change for future developments and as a clue to continue trading in a more environmentally friendly way. In general it is seen that this adaptation and mitigation bring not only benefits to the ports but also bring positive externalities to the surrounding areas and communities.

The next chapter provides the conclusions of the present research, and recommends further investigations for the future in regards to the current project.

CHAPTER 6

Conclusions and Recommendations

The central aim of this project is to analyse the potential environmental adaptabilities of port operations to climate change effects. The study included 10 ports around the world in order to address a number of specific objectives concerning the implementation of sustainable mitigation plans to climate change effects; identification of the types of adaptabilities within the ports; a comparative analysis among the ports; and the assessment of different alternatives using a non-monetary evaluation method in order to observe the benefits and externalities that such adaptabilities may bring to the ports and surrounding areas.

This research intended to demonstrate the importance of integrating climate change effects into the port operations and how this would contribute to diminishing impacts like crane damaging, flooding, interruption of intermodal connections, air and noise pollution, and health and safety of workforce and communities, among others.

Although time and data availability constrain the scope of the project at this point, attempts have been made to analyse valid and reliable information with the use of surveys and case studies. However, it is important to consider that other ports around the world are implementing similar and also different types of mitigation plans to their port operations.

The use of surveys in this study has brought advantages and disadvantages. It was intended to e-mail the survey to 65 ports but difficulties in the delivery of e-mails to the port authorities occurred. Another disadvantage that arose in this study was the low response received from ports (only 12.5%). This has not allowed and limited the determination of an appropriate generalisation and reliability; nevertheless, it has provided a collection of valid data from a variety of different ports around the world and with a low cost process.

The case studies have demonstrated that there are a number of ports already implementing mitigation plans against climate change effects and that the adaptation of equipment, vehicles, and buildings is being undertaken. They have also provided information about economic issues in which investments of millions of dollars have to be allocated to such plans. These investments may be seen as a low incentive for ports that have not yet adapted their port operations. This is due to the long-term sustainable commitment and decisions that are not compatible with the short-term commitments of the investment business.

In general, the results have indicated that the 10 ports investigated are implementing proper mitigation plans against climate change effects. The approach to research different ports provides the effort on make this project as reliable as possible. The solutions that the majority of the ports are implementing today are reduction of GHG emissions, and energy and fuel consumption. Furthermore, it has been observed that five ports have already investigated the vulnerability and the risks that their ports are facing from sea level rise and extreme weather. Some of the sustainability strategies that are being implemented are the integration of alternative fuels, and alternative energy sources like wind power, photovoltaic panels and biofuels; collaboration with terminal operators and parties involved in port operations; integration of green vehicles such as hybrid tugs and trucks; speed reduction of ships; improvements in their infrastructure; new cargo handling equipment like Eco-RTGs; and shore-power facilities.

Also, it has been observed that ports are participating in one or more organisations/associations, that in a national, regional and international level has the advantage of sharing information and knowledge in order to enable other ports to implement strategies already proven to be successful.

The multi-criteria analysis has considered social, economical, financial and environmental issues and has used weighted criteria to determine the optimal sustainable alternative to be developed by ports. This evaluation is only an example for ports on how the adaptation and mitigation of port operations may bring benefits to them and others. The outcome and

conclusions regarding this evaluation have indicated that the third analysed alternative has best satisfied the objectives, but the second option is also recommended. These two alternatives are proposing the integration of mitigation plans that include GHG emissions reduction, energy and fuel consumption efficiency, new sources of energy and new green equipment. Notwithstanding, in the case of the third alternative there is suggested to integrate projections in order to determine the vulnerability to sea level rise and extreme weather and avoid these impacts. The integration of these alternatives will provide ports with adequate services for the international/national trade, as well as to reduce the externalities such as noise, traffic and air pollution that port operations, such as cargo handling equipment, vessels, trucks and trains generate to the surrounding areas.

Recommendations for future research

A number of recommendations, key assumptions and further investigation shall be discussed in the following paragraphs regarding the analysis and outcome of the surveys and case studies as well as for the MCA.

It is recommended that ports around the world that have not yet considered climate change sustainable mitigation strategies in their planning should begin to do so. This should provide them with the appropriate tools for energy and fuel consumption efficiency, as well as benefits in health upon reducing the GHG emissions produced by port operations in the long-term.

It was found that other issues such as terminal access, storage, labelling, weighting, and packaging were not considered in the implementation of adaptation plans for GHG emissions, energy and fuel consumption, sea level rise and extreme weather. It would be important for future studies to research why ports have not included these types of activities into their mitigation plans and consider whether it is due to the difficulty of altering such activities or their minimal effect in terms of climate change adaptation.

Ports that have not yet examined the potential impacts of sea level rise and extreme weather should start considering these issues. The use of modelling and projections is a key tool in order to determine the risks and

vulnerability that each port would have in case these phenomenon should appear.

The multi-criteria analysis has resulted in a number of concerns regarding the subjectiveness of this approach. Although the three assessment criteria have included social, environmental, financial and economic factors, they have been biased to the aims stated for this project. Also, the values that have been assigned to the alternatives for the different criteria have been based on the information gathered in the surveys and case studies without considering other possibilities. The subjective assigned weight factors for the different assessment categories may have influenced the outcome. It is recommended to develop further feasibility studies and cost-benefit analysis in order to determine the value and the amount of investment that is needed for the implementation of sustainable climate change impacts strategies.

To finalise, it is recommended that more ports should be investigated in relation to their position on climate change issues. This would provide further knowledge on the number of ports in the world which are developing sustainable strategies and adaptation for their port operations and management to climate change effects. In the cases where they are not implementing any mitigation plans, research should be done to establish the reasons for the lack of concern in regards to such important issues amongst ports.

REFERENCE

- Alderton, P.M. (2005). **Port Management and Operations**. 2nd Edition. Lloyd's Practical Shipping Guides. Informa Professional, London, UK. 255 pp.

- AAPA. (2009a). **AAPA Mission Statement**. Available: http://www.aapa-ports.org/About/content.cfm?ItemNumber=652&navItemNumber=502 [09/03/2010].

- AAPA. (2009b). **Member Directory**. Available: http://www.aapa-ports.org/About/content.cfm?ItemNumber=715&navItemNumber=1049 [09/03/2010].

- AAPA. (2009c). **World Port Ranking 2008**. Available: http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=900#Statistics [30/05/2010].

- AIVP (2009). **List of members, September 2009**. Available: http://about.aivp.org/spip.php?rubrique1&lang=en&rubriqueactive=1 [02/06/2010].

- AIVP. (2010a). **Stockholm hosts the 5th Greenports Conference in the snow**. 24-25 of February 2010. Available: http://about.aivp.org/spip.php?sommaire&lang=en [08/03/2010].

- AIVP (2010b). **Our means of actions**. Available: http://about.aivp.org/spip.php?rubrique2&lang=en&rubriqueactive=2 [09/03/2010].

- ABPmer. (2007). **Climate Change and Ports**. ABP mer, Marine Environmental Research. Available: http://www.abpmer.co.uk/20071747.asp [03/04/2010].

- APM Terminals. **Innovation**. Available: http://www.apmterminals.com/aboutus.aspx?id=14089 [21/04/2010]

- Atkin, B. (2010). **Experiments, surveys and case studies**. Lecture Notes in Research Methods Course 2010 in MOaM. City University, London.

- Bichou, K. (2009). **Port Operations, Planning and Logistics**. Lloyd's Practical Shipping Guides. Informa Law. London, UK. 364 pp.

- CAPA. **About CAPA**. California Associations of Ports Authorities. Available: http://www.californiaports.org/capa-about.shtml [03/04/2010].

- EPA (2009). **History**. U.S. Environmental Protection Agency. Available: http://www.epa.gov/history/ [09/03/2010].

- EPA, Clean Ports USA. (2009a). **Basic Information**. U.S. Environmental Protection Agency Available: http://www.epa.gov/otaq/diesel/ports/basicinfo.htm [09/03/2010].

- EPA (2010a). **Climate Change or Global Warming**. U.S. Environmental Protection Agency. Available: http://www.epa.gov/climatechange/basicinfo.html [03/03/2010].

- EPA, (2010b). **Basic Information: Science.** U.S. Environmental Protection Agency. Available: http://www.epa.gov/climatechange/basicinfo.html [03/03/2010].
- EPA (2010c). **Our Mission and What We Do.** U.S. Environmental Protection Agency. Available: http://www.epa.gov/epahome/whatwedo.htm [17/06/2010].
- EcoPorts. (2006a). **Vision and Mission**. Available: http://www.ecoports.com/page.ocl?version=&mode=&pageid=12 [24/02/2010].
- EcoPorts, (2006b). **EcoPorts and ESPO: ESPO supports ECOPORTS Foundation statement**. Available: http://www.ecoports.com/page.ocl?pageid=120 [25/02/2010].
- EcoPorts. (2006c). **EcoPorts and the European Ports.** Available: http://www.ecoports.com/page.ocl?mode=&version=&pageid=119 [25/02/2010].
- EcoPorts. (2006d). **Environmental Issues**. Available: http://www.ecoports.com/page.ocl?pageid=24 [25/02/2010].
- ESPO (2005). **Members**. Available: http://www.espo.be/About_ESPO/Members.aspx [16/06/2010].
- ESPO. (2010). **Mission Statement**. Available: http://www.espo.be/About_ESPO/Mission_Statement.aspx [09/03/2010].
- Fairplay. (2009). **From grey to green**. APM Terminals. Rotterdam/Europort. 29 October 2009. Available: http://www.apmterminals.com/mediacenter.aspx?id=7125 [19/04/2010].
- Green Port. (2009). **APM Terminals and the eco-efficiency philosophy**. Nomvembre 2009, Issue 6. Available: http://www.apmterminals.com/mediacenter.aspx?id=7125 [21/04/2010].
- IACP (2010). **IAPC (International Association Cities and Ports).** Available: http://www.ehoalaport.com/iacp [09/03/2010].
- IAPH. (2006a). **Mission**. The International Association of Ports and Harbours. Available: http://www.iaphworldports.org/about/mission.html [09/03/2010].
- IAPH. (2006b). **WPCI Mission Statement**. Available: http://www.iaphworldports.org/wpci_2008/mission.html [16/06/2010].
- IAPH. (2008). **Media Release: The World Ports Climate Initiative launched by IAPH.** November, 28, 2008. The International Association of Ports and Harbours. Available: http://www.iaphworldports.org/wpci_2008/index.html [03/04/2010].
- ICF international (2008). **Planning for Climate Change Impacts at U.S. Ports.** White Paper. Prepared for the U.S. Environmental Protection Agency. July 2008.

- International Maritime Organisation (IMO). (2002). Available: http://www.imo.org/ [03/04/2010].
- IPCC. (2007). **Climate Change 2007: Synthesis Report. Summary for Policymakers**. Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
- Lloyd's Register Fairplay. **Ports & Terminals Guide 2009-2010.** Volumes 1-4. ihsFairplay.
- Long Beach Harbour Department. (2005). **Green Port Policy**, White Paper. Port Of Long Beach. Available: http://www.polb.com/environment/green_port_policy/default.asp [19/04/2010].
- MARAD. **About us**. Maritime Administration. Available: http://www.marad.dot.gov/about_us_landing_page/about_us_landing_page.htm [03/03/2010].
- Nicholls, R.J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Jan Corfee-Morlot, Jean Chateau, & Muir-Wood, R. (2007). **RANKING OF THE WORLD'S CITIES MOST EXPOSED TO COASTAL FLOODING TODAY AND IN THE FUTURE.** Executive Summary. OECD. Environment Working Paper No. 1 (ENV/WKP(2007)1).
- OECD (2008). **Economic Aspects of Adaptation to Climate Change. Costs, benefits and policy instruments.** Organisation for Economic Co-operation and Development publication.
- Oppenheim, A.N. (1992). **Questionnaire Design, Interviewing and Attitude Measurement**. New Edition. Continuum, New York. 303 pp.
- Ports Australia (2010) **About Us**. Available: http://www.portsaustralia.com.au/about/ [08/06/2010].
- Port of Felixstowe (2010). **Environmental Report 2009**. Available: http://www.portoffelixstowe.co.uk/publications/ [21/04/2010].
- Port of Rotterdam. **Jaarverslag 2008**. Available: http://www.portofrotterdam.com/en/home/results.jsp?query=rotterdam+climate+initiative [21/04/2010].
- Port of Rotterdam, **Annual Report 2007**. Available: http://www.portofrotterdam.com/en/news/publications/annual_report/index.jsp [21/04/2010].
- Port of Rotterdam, **Annual Report 2008**. Available: http://www.portofrotterdam.com/en/news/publications/annual_report/index.jsp [21/04/2010].
- Port of Rotterdam. (2004). **Port Vision 2020. Space for Quality**. Available: http://www.portofrotterdam.com/en/home/results.jsp?query=environment [19/04/2010].

- Port of Rotterdam. Maasvlakte 2. **Sustainalbe Operations**. Available: http://www.maasvlakte2.com/en/index/show/id/210/Sustainable+operations+ [19/04/2010].
- PSA (2008). **"Protecting the Environment – A Terminal Operator's Perspective"**. Power Point presentation. 9 July 2008.
- Robson, C. (2002) **Real world research.** 2nd edition. Blackwell, Oxford, UK. 599 pp.
- Stopford, M. (2009). **Maritime Economics**. 3rd edition. Routledge, London. 815 pp.
- Sydney Ports. **Mayor Projects**. Available: http://www.sydneyports.com.au/port_development [17/06/2010]
- The Port Authority of New York and New Jersey (PANYNJ). (2009a). **A Clean Air Strategy for the Port of New York and New Jersey.** Port Authority Initiatives. Available: http://www.panynj.gov/about/port-initiatives.html [29/04/2010].
- The Port Authority of New York and New Jersey (PANYNJ). (2009b). **Tenant Initiatives** Available: http://www.panynj.gov/about/port-initiatives.html [29/04/2010].
- The Port Authority of New York and New Jersey (PANYNJ). (2009c). **Port Regional Initiatives** Available: http://www.panynj.gov/about/port-initiatives.html [29/04/2010].
- The Port Authority of New York and New Jersey (PANYNJ). (2010a). **Climate Change and Air Quality**. Available: http://www.panynj.gov/about/climate-change-air-quality.html [23/04/2010].
- The Port Authority of New York and New Jersey (PANYNJ). (2010b). **Energy**. Available: http://www.panynj.gov/about/energy.html [23/04/2010]
- The Port of Long Beach. (2010a). **Investing in the Future. The Port Of Long Beach Annual Report 2008**. Available: http://www.polb.com/news/pub/annual/default.asp [20/04/2010].
- The Port of Long Beach. (2010b). **Clean trucks**. Available: http://www.polb.com/environment/cleantrucks/default.asp [20/04/2010]
- The Port of Long Beach. (2010c). **CAAP 2010 Draft Final**. Available: http://www.polb.com/environment/air/caap.asp [20/04/2010].
- The Port of Long Beach. (2010d) **Power Point Presentation on the Draft 2010 CAAP update**. Available: http://www.polb.com/environment/air/caap.asp [20/04/2010]
- The Port of Los Angeles. (2010a) **Climate Action Plan**. Available: http://www.portoflosangeles.org/environment/studies_reports.asp [20/04/2010]

- The Port of Los Angeles. (2010b). **Expanded Greenhouse Gas Inventory 2008**. Available: http://www.portoflosangeles.org/environment/studies_reports.asp [21/04/2010].

- The Port of Los Angeles. (2010c). **Sustainability Assessment and Plan Formulation**. Available: http://www.portoflosangeles.org/environment/studies_reports.asp [20/04/2010].

- UKCIP (2010). **Adaptation Wizard. Case Study**. **Port Of Felixstowe**. Available: http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=686&Itemid=560 [19/04/2010].

- United Nations. (2010). **The United Nation Convention on the Law of the Sea (UNCLOS)**. Avialable: http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm [28/02/2010].

- UNCTAD (1996). **Port Organization and Management.** United Nations. Trade and Development Board. Available: http://unctad.org/ [01/03/2010].

- UNCTAD (2008). **Maritime transport and the climate change challenge.** United Nations. Trade and Development Board. Available: http://unctad.org/ [01/03/2010].

- Verhaeghe, R.J., (2007). **Reader: Plan & Project Evaluation, CT4740**. Delft University of Technology.

- Wooldridge, C., & Stojanovic, T. (2004). **Integrated environmental management of ports and harbours. The European experience – from policy to practice.** Part III, Chapter 10 IN: Pinder, D., & Slack, B. (2004). **Shipping and Ports in the Twenty-first Century. Globalisation, technological change and the environment**. Routledge, Teylor & Francis Group. London, UK. 281 pp.

Appendices

Appendix A

Survey

English Version:

1. What is your name, and your job position within the port?
2. What is the name of the Port?
3. Is the port organisation aware of the potential impacts of climate change? What impacts are recognised as having an effect on the port and its operations?
4. Are there any major or minor developments for the port that are being carried out at the present time? If yes, please give details of the plans.
5. Are there any future developments/expansions being planned for the port? If yes, please give details of the plans.
6. If the port has implemented environmental mitigation plans that relate to issues other than climate change, what were they and what were the results?
7. If new port developments are being undertaken/planned, does the new development consider mitigation or adaptation to climate change issues such as:
   - sea level rise;
   - temperature increases;
   - Greenhouse gas emissions mitigation; and
   - extreme weather (storms, flooding).

   If yes, please indicate which issue is considered and why?
8. Please give details of the mitigation and adaptation plans that have been/will be implemented within the port and its operations to deal with the issues selected in Question 6. What is the expected outcome of these adaptations, and/or how successful have they been so far?
9. Is the port involved in any organisation such as ESPO, IAPH, AAPA, AIVP, EcoPorts or any other?, If yes, please indicate which one.
10. Is the port involved in any programme or organisation that offers any type of environmental certification? If yes, please give details of the company and certification. If no, please give reasons why and are there any plans to obtain this certification in the future?
11. Has a cost-benefit analysis been done in regards to any mitigation and adaptation plans undertaken or planned by the port? If yes, please give details and explain what externalities were identified?

Disclaimer: The information provided here will be **Confidential** and used for writing a dissertation in Maritime Operations at City University London. No information will be published in any other source without the organisation permission. Should you need any other information please do not hesitate to contact me via e-mail: Jimena.haza-vidal.1@city.ac.uk.

Appendix B

Table B-1. List of ports.

Europe

UK
- FelixStowe
- Inverness
- Southampton
- London
- Lowestoft

Netherlands
- Rotterdam
- Scheveningen
- Amsterdam

Belgium
- Antwerp

Spain
- Cadiz
- Gijon

Greece
- Thessaloniki
- Alejandroupolis

Denmark
- Copenhagen

Iceland
- Keflavik-Njardvik

Italy
- La Spezia

Norway
- Narvik

Portugal
- Lisbon

Sweden
- Koping

Asia

Singapore
- Singapore

China
- Shanghai

Japan
- Yokohama

Malaysia
- Bintulu

Thailand
- Pattani

Maldives
- Male

America

US
- Baton Rouge
- Long Beach
- NY & NJ
- New Orleans

Mexico
- Veracruz
- Ensenada
- Mazatlan

Argentina
- Buenos Aires

Bermuda
- Freeport

Canada
- Churchill
- Halifax
- Vancouver

Panama
- Bahia Las Minas

Trinidad & Tobago
- Brighton

Oceania

Australia
- Portland
- Port Walcott
- Mourilyan
- Cairns
- Sydney

New Zeland
- Auckland
- Tauranga

Africa

South Africa
- Cape Town
- Durban

Information from: Lloyd's Register Fairplay. Ports & Terminals Guide 2009-2010.

Appendix C

Survey responses from:

Sydney Port Corporation
Christa Sams, Environment Operations Manager

Port of Greater Baton Rouge
Greg Johnson, Director of Business Development

Port of Churchill
Darryl Balasko; Marketing Analyst

Port of Antwerp
Geert Schrooten, Environmental Advisor

Port of Gijón (Autoridad Portuaria de Gijón)
José Moyano Retamero. Director de Infraestructuras