IHS is the international institute of urban management
of Erasmus University Rotterdam

IHS
Making cities work

MSc Programme in Urban Management and Development

Rotterdam, The Netherlands

September 2014

Thesis

Title: Port cities and climate change: actions for resilience

Alexandra Tsatsou

Supervisor: Stelios Grafakos

Specialization: Urban Climate Change Management

UMD 10

MASTER'S PROGRAMME IN URBAN MANAGEMENT AND DEVELOPMENT

(October 2013 – September 2014)

Port cities and climate change: actions for resilience

Alexandra Tsatsou

Supervisor: Stelios Grafakos

UMD 10 Report number: -

Rotterdam, September 2014

Summary

Under global developments and circumstances such as the vast urbanization rate and climate change, port cities stand on the edge of imminent socioeconomic disasters. The increasing interconnectedness of the global economy, combined with the expanding, global importance of ports as trade nodes intensify this risk and highlight the need for adaptation.

Although the port city as an urban typology has been studied from various perspectives, and the global interest for the port city is growing, there is currently a lack of identified adaptation responses from both the port and the city. Due to the dual identity of the port city and the gradual separation of its components after the industrial era, the need to examine these two components separately and adequately, but under the recognition that they form one single urban entity is identified.

This research, based on primary and secondary data, focuses on gathering and analysing the adaptation responses of 40 port cities in 10 countries worldwide. Eight types of adaptation actions are analysed for the port and the city respectively, in relation to various attributes that describe the port, the city, and the port-city relationship. These attributes include the port city exposure in monetary terms, the level of dependence of the city on its port, the size, performance, formation process of the port, as well as the port authority types. Regarding the city as a municipality and taking into account its urban form, the attributes that are examined are the city's population density, welfare and location – namely whether it is a delta port city or a coastal port city.

After analysing the data and identifying the correlations and levels of significance of the findings, conclusions are made regarding the relations between the various variables and the types of adaptation actions of the port and the city.

In the conclusions, the focus of the port on its performance and the sensitivity of the city's adaptation response in relation to the port prevalence in the port-city system is generally identified. However, this connection is seen as an opportunity that can enhance the adaptation response of port and the city, and lead to port city climate resilience.

Keywords

Port cities, climate change, adaptation actions, local government, port authority

Acknowledgements

Conducting this thesis would not have been a valuable and enjoyable process without the support and assistance of all the involved professors, professionals, and my friends.

The thesis supervisor, Stelios Grafakos, has been the person who stimulated the structure and conduct of the research in a stable, motivational and enlightening manner. The time he dedicated and his constant support and guidance played a major role in the understanding of the topic and the acquisition of knowledge on a wider and relevant perspective. As an academic and a teacher, he supported personal choices and assisted in combining them with scientific background in a creative way.

Moreover, Michiel Nijdam provided substantial and influential input at critical points of the research. His advice and expertise in the port economics sector triggered valuable additions to the structure and content of the research.

The professors and staff of IHS also contributed in direct and indirect ways. Firstly, Spyridon Stavropoulos through his practical support regarding technical issues on the data collection and analysis. In addition, Charmae Nercua and Daniel Lobato Palazón through providing contacts from the IHS Alumni Network. Apart from this direct contribution, professors and academic staff of IHS provided useful input through the colloquia and advanced the involvement with the research subject.

As this thesis required communication with cities around the world, it would not have been possible without the support of my classmates and friends, but also the people who assisted without being personally related. Their collaboration in translating documents and contacting people in port authorities and municipalities was the most valuable and enjoyable part of this study. For these reasons I would like to mention Aakarsh Shamanur, Aris Erotas, Antonis Michail, Bernardo Mendonça, Emina Ahmetovic, Elisa Puga, Rania Pappa, Polyvios Dimiou, Swati Pujari, and Georgios Kalantzis.

Last but not least, the professionals within the environmental departments of port authorities around the world have to be mentioned, for spending some of their time to contribute to this research. Their willingness to support academic research, as well as their dedication and professionalism played a major role in completing this study.

On a personal basis, the support of my family has been the basis on which my personal and academic development is founded on.

I would like to heartfully thank all the people mentioned above for their contribution to this research.

Abbreviations

CC	Climate Change
CCA	Climate Change Adaptation
CCM	Climate Change Mitigation
cCCR	carbon*n* Cities Climate Registry
ICLEI	Local Governments for Sustainability
IHS	Institute for Housing and Urban Development
ICZM	Integrated Coastal Zone Managemen
IPCC	Intergovernmental Panel on Climate Change
LG	Local Government
OH&S	Operational Health and Safety
RCI	Relative Concentration Index
PA	Port Authority
SLR	Sea Level Rise
TEU	Twenty-foot Equivalent Unit
UNFCCC	United Nations Framework Convention on Climate Change

Glossary of terms

Adaptation

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects. (IPCC 2014)

Adaptation needs

The circumstances requiring action to ensure safety of populations and security of assets in response to climate impacts. (IPCC 2014)

Adaptation opportunity

Factors that make it easier to plan and implement adaptation actions that expand adaptation options, or that provide ancillary co-benefits. (IPCC 2014)

Adaptation options / actions

The array of strategies and measures that are available and appropriate for addressing adaptation needs. They include a wide range of **actions** that can be categorized as structural, institutional, or social. (IPCC 2014)

Adaptive capacity

The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. (IPCC 2014)

Climate change

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. (IPCC 2014)

Co-benefits

The positive effects that a policy or measure aimed at one objective might have on other objectives, irrespective of the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on local circumstances and implementation practices. Co-benefits are also called ancillary benefits. (IPCC 2014)

Disaster management

Social processes for designing, implementing, and evaluating strategies, policies, and measures that promote and improve disaster preparedness, response, and recovery practices at different organizational and societal levels. (IPCC 2014)

Disaster risk reduction (DRR)

Denotes both a policy goal or objective, and the strategic and instrumental measures employed for anticipating future disaster risk; reducing existing exposure, hazard, or vulnerability; and improving resilience. (IPCC 2014)

Early warning system

The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. (IPCC 2014)

Exposure

"The extent to which an activity. Group, region or resource is exposed to significant climatic variations" (Nursey-Bray et al. 2013)

Flood

The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. (IPCC 2014)

Hazard

The potential occurrence of a natural or human-induced physical event or trend, or physical impact, that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts. (IPCC 2014)

Port city (urban typology)

"A city exerting port and maritime activities. A communication node between land and maritime networks developing auxiliary activities and having a strong influence on the spatial organization of the outlying region." (Ducruet n.d.)

Port-city (system)

"The physical environment surrounding ports […] and the social context within which the port exists, including the elements of the community that are directly or indirectly involved in port operations" (Nursey-Bray et al. 2013)

Resilience

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner. (World Bank 2012)

Risk

"The probability of the effect occurring, and the consequence of the event"

(UNCTAD 2011)

Risk management

The plans, actions, or policies implemented to reduce the likelihood and/or consequences of risks or to respond to consequences. (IPCC 2014)

Vulnerability

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (IPCC 2014)

Sensitivity

The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise). (IPCC 2014)

Storm surge

The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place. (IPCC 2014)

Urbanization

The increasing share of a nation's population living in urban areas (and thus a declining share living in rural areas). Most urbanization is the result of net rural to urban migration. […] This definition makes the implications of urbanization distinct from those of urban population growth or those of the physical expansion of urban areas, both of which are often treated as synonymous with urbanization. (Satterthwaite et al. 2010)

Table of Contents

List of Tables

List of Charts

List of Figures

Chapter 1: Introduction

1.1 Background

Globally, the awareness for climate change and urbanization is growing, as their consequences become increasingly apparent. The climate challenges that the planet is facing vary between rising sea levels, global warming and increasingly intense weather events such as storms. At the same time, the population living in urban areas is over 50% of the global population for the first time with expectations that 70 million people per year will be moving to urban areas for the next decades. (UN Habitat 2008)

The direct threats from both of these phenomena, especially in rapidly expanding cities, are prominent: flooding, heat/cold waves and hazard risk from exposure to extreme weather conditions. The consequences can vary from impacts on energy and food supply, to health and lost lives. (UN Habitat 2008)

Coastal areas are highly threatened by the consequences of both climate change and urbanization as 40% of the global population lives within 100km from the coast. According to UN Habitat (2008), 100 million people live less than one meter above sea level. While, at the same time "between the 1950s and 1990s, there was a 50 per cent increase in extreme weather events associated with global warming" at coastal areas. (UN Habitat 2008)

Mitigation of climate change impacts at the international level, with reduction of emissions, efficient energy supply and production, technological improvements and optimization of transport and building sectors is a prominent necessity. However, at the same time there is the need to focus also on adaptation and ensure the ability of cities to resist to and recover from climate hazards effectively and efficiently – in a timely manner. (World Bank 2012) Focusing on infrastructural resilience can be a first step, and provide conditions and opportunities for institutional, economic and social resilience to be established as well.

1.2 Problem Statement

Port cities, the coastal urban typology which attracts increasing attention during the last decades (Ducruet n.d.), are on the frontline of climate change and urbanization due to two reasons: their geographic position and the concentration of economic activity. Currently, 16 of the 20 most populated cities in the world are port cities (Demographia 2014). As 80% of the global trade is seaborne (Becker et al. 2014) port cities the main recipients of trading activity worldwide. Their importance for the economy of the regions is crucial, as they are key nodes for the global supply chain networks.

This high concentration of population, investments and economic activity, combined with the high exposure of port cities to climate extremes, increases the need for measures to adapt to the new climatic circumstances. According to Hanson et al. (2010) "40 million people (in port cities) […] are currently exposed to a 1 in 100 year coastal flood event", while "by the 2070s, the total population exposed could grow more than threefold due to the combined effects of sea-level rise, subsidence, population growth and urbanisation". The assets exposed in port cities globally could grow more than tenfold by that time (Hanson et al. 2010).

For the aforementioned reasons, the requirement of climate adaptation in port cities is urgent. However, currently ports and cities are more focused on their environmentally sustainable performance while adaptation to climate change receives less attention. Mostly in places where climate hazards have already taken place (for example New Orleans, New York) is adaptation regarded as an issue of high priority.

Regarding the information available on climate adaptation and mitigation actions adopted by local governments, apart from scattered sources, there are platforms and initiatives of regional or global level where municipalities are able to publish their action plans and actions. Examples are the Carbon*n* Cities Climate Registry by ICLEI (which includes energy and emission performance and commitments, as well as mitigation and adaptation actions from 423 municipalities worldwide), as well as the Covenant of Mayors, a European initiative based on the emission goals of the European Union for 2020.

These platforms are important sources of transparency concerning local decisions, as they are presented globally, forming in this way a means to promote "measurable, reportable and verifiable climate action" worldwide (Moncuit 2013). Although they are functioning on a voluntary basis and to a large extent without validated information, they already provide a strong base and starting point for the wider identification of climate issues, accountability and comparability of responses to climate change.

Regarding the ports themselves -positioned on the very edge of the port cities high exposure risk- the focus is also mainly on environment and sustainability. Their environmental performance is in many cases being monitored through platforms like the European EcoPorts which has also created port-specific environmental management tools (SDM) and a port environmental management certification (PERS). Worldwide, the ISO 14000 certification for Environmental Management is also used for this reason.

Nevertheless, there are no coordinated platforms regarding port adaptation, although guidelines for port adaptation to climate change have been published by various organizations worldwide. Increasing attention is being drawn to the subject during the last years, but adaptation activity is still much less compared to mitigation (Castán Broto & Bulkeley 2013).

At the same time, climate adaptation actions in ports, although existing, may be difficult to identify as such. The reason is that in many cases they are embedded in operations management, safety measures, engineering or other procedures within a port. As an example, RMIT University proposes a "hybrid vulnerability/risk management approach" on port adaptation, based on the ISO 31000 on Risk Management (Scott et al. 2008). This is an apparent proof of the multidisciplinary nature of adaptation, which is frequently pursued without specifically climatic reasoning (Castán Broto & Bulkeley 2013).The widespread application and natural tendency for adaptation actually highlight its importance, and prove the additional advantages that can be achieved by a coordinated and integrated approach between the various disciplines and scales (Cash et al. 2006).

Specifically for port cities, because of their "dual" nature – as they constantly divided between the urban/land based and marine/water based functions - an integrated climate change strategy of port and city is of vital importance. The increasing complexity of the port-city system and the overlap of authority responsibilities can complicate the adoption of a holistic and adequate climate approach. As Ducruet & Lee (2006, 107) highlight, "the nature of the relationships between ports and port cities is an old question with few answers". The context – specific and aforementioned multidisciplinary nature of adaptation makes the introduction of integrated climate strategies in the port-city system an intricate issue.

In the words of Hanson et al. (2010)“The large potential port city asset exposure on its own (i.e. up to US$35,000 billion in 2070s, in PPP, 2001USD) argues for a combined effort across all scales of governance - from global to national and local, between public and private actors”.

1.3 Research objectives

The objective of this research is to identify the adaptation actions of port cities around the world, and explore the factors that are connected to their adoption. Specifically, the study aims to collect and categorise adaptation actions taken by the port authorities (PAs) and local governments (LGs) of port cities, respectively.

Currently, although port cities are examined regarding their exposure risk, vulnerability, adaptation cost, port-city relationship, competitiveness and sustainable development, their response to their climate risk has not been recorded on a wider scale or consistent basis. Moreover, the previously mentioned characteristics have not been correlated. Although adaptation of ports and port cities is being discussed separately, these two subjects have not been combined and studied for the same ports / port cities in order to have a holistic view of the adaptation response level of port cities.

In this research, a sample of port cities around the world for which all the necessary data is available will be examined from the port and the city perspectives. The factors that will be examined alongside the PA actions are related to the port’s physical characteristics, economic performance and PA type. Similarly, the actions of the cities will be examined in relation to the city’s attributes: population density, welfare, location. The aspects that the research aims to associate with both the port and the city, as mutual attributes of both entities, is the exposure of the port city as a geographic location to flooding and subsidence, and the port-city relationship and cooperation.

Figure 1: The 40 port cities selected for the research

1.4 Research question

The research question that will be examined throughout this research is:

Which characteristics of port cities are related to the adoption of distinct types of adaptation actions by the local government and the port authority respectively?

The study will explore the relationship between port city attributes with the adoption of specific types of climate adaptation actions. However, first the adaptation actions of the port authorities (PAs) and the local governments (LGs) will be identified and categorized. Specifically, the relations that will be examined are the following:

1. Port city exposure in relation to the adaptation actions of the port and the city

The port city exposure in monetary terms, as the effect of CC and anthropogenic activity on the vulnerability of population and assets, will be associated with the port and city actions. The objective is to examine whether the increase of exposure will coincide with higher and wider (in action typologies) adaptation activity of the port and the city respectively. The main sources of data for the exposure – adaptation actions correlation will be the studies of Nichols et al. (2008) and Hanson et al. (2010), who identify the 136 most exposed port cities around the world, based on future climatic and socioeconomic scenarios.

2. Port – city relationship and port authority – local government collaboration in relation to the adaptation actions of the port and the city.

The port-city Relative Concentration Index (RCI), as developed by Ducruet (Ducruet & Lee 2006), describes the concentration of port-city functions, as a function of their centrality and intermediacy. The indicators utilized for the composition of this index are the container throughput of the port and the city's population, two factors that add to the city's assets under exposure with their development. Therefore, the assumption that the higher the RCI, the more adaptation actions will be adopted by the port and the lower the RCI the more actions will be adopted by the city will be tested.

At the same time, the collaboration of the PA with the LG will also be examined, in order to identify the port city typologies that project a stronger connection of these two components.

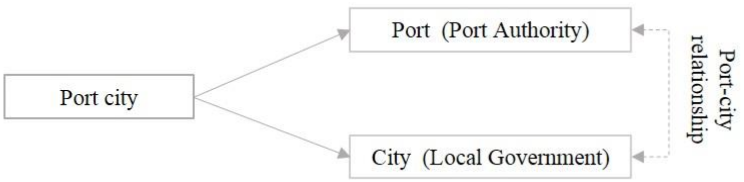
3. Port attributes in relation to the types of adaptation actions of the port

The port characteristics that will be examined are the port size, the port formation process (natural/artificial port), port performance (in TEUs) and PA typology. The hypothesis regarding the size and performance is that the larger and busier the port, the more important is the need for adaptation - and therefore the more the adaptation actions. Regarding the type of PA (public port: national/regional/municipal, public/private, private, landlord port type management) the research will explore the relation between the different authorities and the adoption of types of actions.

4. City attributes in relation to adaptation actions of the city

The relationship between the city's population density, city GDP per capita and whether the city is a delta or coastal city, with the adopted actions will be examined. Population density is a characteristic that increases the exposure risk of the urban population, while city GDP per capita is an attribute that increases the assets at risk. These two exposure risk factors have also been identified in the literature (Nicholls et al. 2008; Hanson et al. 2010). Moreover, an effort to distinguish between the responses of delta and non-delta (coastal) port cities will be attempted. As delta cities include fluvial flood plains and fertile lands, they have historically been important trade centres (Molenaar et al. 2014). However, this characteristic currently increases their exposure risk, and distinguishes them as a city typology that requires specific adaptation attention. According to Hanson et al. (2010), 19 out of the 30 most exposed port cities around the world are located on deltas.

Figure 2: The port city divided to its elements that will be examined in this study



1.5 Significance of the study

As mentioned, port cities are being studied in literature as a distinct urban typology with increasing interest, due to their special spatial and economic characteristics. Their CC exposure, vulnerability, competitiveness and need for resilience are characteristics that are highlighted, as well as the cost of their adaptation requirements.

However, the actual response of port cities to their climate risk has not been recorded, and the factors that are connected to this response (such as port city spatial and functional attributes) have not been researched. As Hanson et al. (2010) mention, “data on [port city] defences is sparse and no systematic analysis is possible”. The goal of this research is to map and analyse the current adaptation response of port cities on global level, through primary and secondary data on the actions of the port, the city. Moreover, the factors that are related to the adoption of adaptation actions will be explored.

In addition, although the relationship between the two sides of the port-city system has been adequately studied from some perspectives, the dual nature of the system has not been associated with the adaptive capacity and adaptation response of port cities. This study aims to attempt this association as well, and identify the current adaptation activity of port cities as a system that consists of a port and a city respectively.

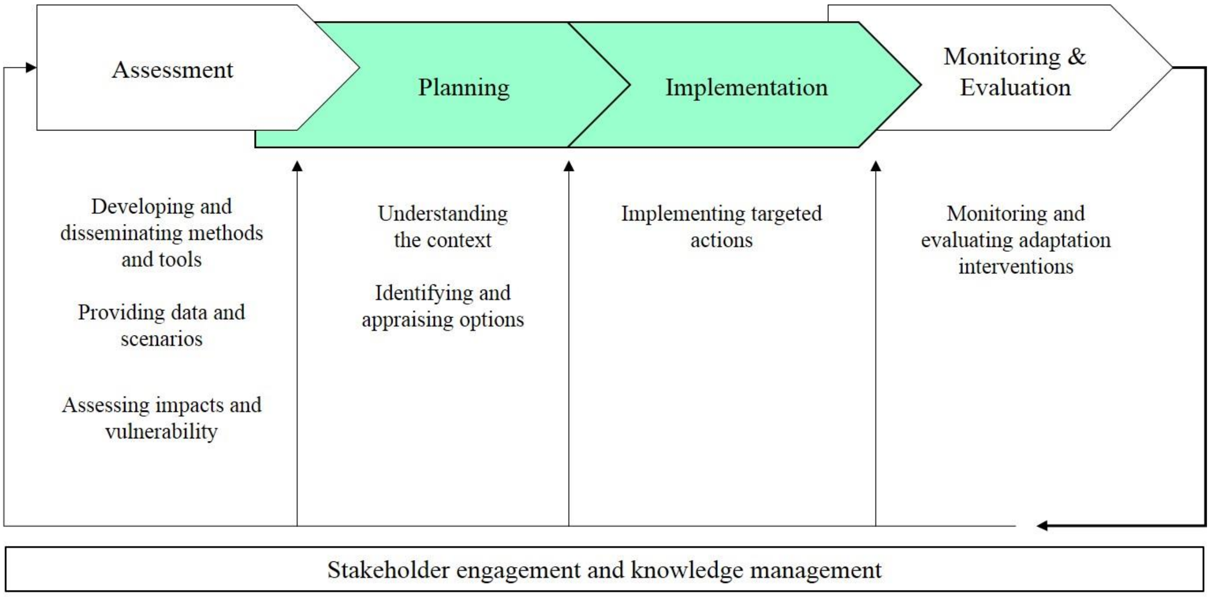
Through providing a further understanding of the way that the port-city system functions combined to its spatial attributes, and by relating these aspects to the port-city system climate exposure, the study aims to assist future research in identifying the co-benefits and opportunities for collaboration between the port and the city and ways to optimise and take complete advantage of the adaptation processes.

1.6 Scope and limitations

As described, the scope of this research is to examine a sample of 40 port cities in order to examine the attributes that are related to the adoption of actions from their LGs and port authorities.

Within the four components of the adaptation process as identified by UNFCCC (2011) (assessment of climate impacts and vulnerability, planning, implementation of adaptation measures, monitoring and evaluation of adaptation actions) this research will focus only on planned and implemented adaptation actions.

Figure 3: The four components of the adaptation process (adjusted from UNFCCC 2011)



The current sensitivity and vulnerability of the cities will not be assessed or examined – but only their exposure risk as a result of their geographic position will be referred to from previous studies (Hanson et al. 2010). Moreover, the level of risk reduced and the adaptive capacity reached through the planned/implemented actions will not be calculated, as it requires different and extensive of research.

Potential recommendations regarding port and city collaboration and adaptation of specific types of adaptation actions will be attempted. In addition, the generalization of the research findings based on the selected sample will be pursued.

The selection of port city sample, as well as the attributes and measurement units utilized, were done according to the relevant data availability from reknown sources. Due to this method, key port cities with ports of global importance (like Shanghai, Singapore, Rotterdam, Guangzhou, Antwerp) are not part of the research. However, this provides the opportunity to study a wider variety of port city scales and types, as the selection criteria are not related to port size and performance. In addition, it provides the challenging chance to collect information on ports that have not been extensively studied before.

Chapter 2: Literature review

2.1 Port-cities and their importance as a distinct urban typology

2.1.1 The port city as a concept

A “port city” is, in a broad sense, an urban settlement with immediate connection to the sea or navigable river. Its main characteristic is the presence of a harbor, with the ability of docking ships. However, a definition of the port city covering all aspects of its complex nature, does not exist in literature. As Ducruet (n.d.) highlights, many definitions may appear according to the respective field of study. However, as the interest in port cities is becoming wider, the concept itself is actually blurring.

Ducruet identifies a “fragmentation of port-city research”, and suggests at first to clarify the concept of the “port city” itself, and subsequently to research the two components (port and city) and their functions separately and adequately. Nevertheless, a general description to which we could conclude is that a port city is “a city that is exerting port and maritime activities” and also “a communication node between land and maritime networks”. (Ducruet n.d.)

As derives from the previously presented definition, the term “port city” conveys information about both the geographical characteristics and the activity of the city. It describes a type of settlement where geography, morphology, urban and economic functions create complex dynamics, driven by the interactive relationship between the port and the city. Economy, society and spatial form evolve under the influence of variables depended on the regional and global developments - but also on the port city itself. According to Daamen & Vries (2013), the attributes that define the relations between port and city derive from governmental, institutional, jurisdictional and regulatory frameworks. As a consequence, they directly affect the port city’s urban, spatial and social character, as well as economic aspects of both the port and the city.

2.1.2 Port cities as an urban typology in literature

Hoyle (1989), presenting a typology of studies regarding port cities, 25 years ago, identified the following categories:

Table 1: Typology of port city studies (after Bird) (source: modified by Hoyle 1989)

Study typology	Description
Historic-genetic studies	Origins and development of ports and port systems, in the hinterland and foreland contexts.
Economic studies	Ports as most economic point for industrial location, and investment appraisal for port development
Ports and regional development	The role of ports in the context of national and regional transport systems and economic development
Ports and the technology of maritime transport and cargo handling	The impact on ports of unitisation, containerisation, bulk transfer methods and related developments
Set comparisons	Comparative studies of groups of ports, systems approaches
Ports and development planning	Studies of ports in the context of plans for the future development of cities, industries and regions
Ports and the global maritime transport system	Studies of the world system in relation to technological change, specific commodity flows or global economic trends
The port-city interface	Studies of the separation of ports and cities, of abandoned port areas in inner cities, and of waterfront redevelopment

In 2014, the prevailing study typologies on port cities remain, although the increasing interest in port cities has added more perspectives from which they are studied. An important addition deriving from globalization is the introduction of port city competitiveness studies (Merk 2013), (Tongzon & Heng 2005) and also literature related to environment and CC (Peris-Mora et al. 2005). Regarding specific case studies there are vulnerability assessments and adaptation guidelines (Scott et al. 2008), (Nursey-Bray et al. 2013) as well as environmentally sustainable port management reports (Luo & Yip 2013), (Darbra et al. 2005). During the last five years, CCA studies have been conducted as well, focusing mainly on the port side of the port city (Becker et al. 2014; Becker et al. 2011; EBRD 2011; Ng et al. 2013)

However, as Ducruet and Lee (2006) argue, the port-city issue is seldom being approached holistically in literature, but only unilaterally: either by the architect/urban planner's perspective, focusing on land use and urban design issues and ignoring the port area as an "alien activity", or by the port specialist's perspective, focusing on port management, performance and economics -dismissing the urban environment that provides the ground for this port activity to evolve. Moreover, as the same authors highlight, most port city related research addresses specific case studies, the scope of which is led by the existence of the port and not by the concept of city and port co-existence in a wider perspective. They identify a gap on literature regarding the relationship between the port and the city, at the same time arguing that these two aspects should be studied separately, as they require specific attention, but still within the port city spectrum.

As Becker (2014) mentions, except from the case studies and vulnerability assessments, the other type of available studies on port-cities are mostly macro level risk and vulnerability indices, which focus on either the global level, or specific groups of ports and port-cities.

2.1.3 The importance of port cities as economic nodes

Throughout the various study fields, the importance of the economic function of port cities attracts the attention in relation to the rest of their attributes. As İleri et al. (2012) mention, in the past port cities used to be referred to as "cities of commerce" - an obvious advantage for the city and the citizens, who had the ability to improve their financial and social status through maritime activities.

Nowadays, Merk (2013) refers to them as "facilitators of trade" mentioning that shipping goods by sea is seven times cheaper compared to other shipping methods. In addition, due to the increasingly interconnected nature of the world economy and supply chains, the role of port cities as connectivity nodes in the global economic networks enhances their economic profile. They are logistics hubs, maritime sector clusters, as well as nodal points for tourism (Hanson et al. 2010) and (İleri & Mansel 2012).

The main drivers of this process during the last decades have been containerization and globalization. However, this development has shifted the focus of ports on efficiency and performance in order to be competitive in the global markets. According to Merk (2013) port efficiency was identified as the most critical aspect by ports themselves, even in relation to quality of infrastructure, connections with other ports and private sectors participation. The prioritization of port performance is justified by the fact that ports are the main stimulants for the port city's economy and growth, due to their strategic role between production, commodity networks and logistics infrastructure. An example illustrating the economic importance of ports and coastal areas, is that within the European Union 35% of the total GDP is produced on the coastal zones (UNCTAD 2011).

To highlight the role of the ports as global hubs, UNCTAD (2011) describes the series of disasters in Japan, in 2011. As the result of an earthquake, the tsunami that followed, and the subsequent nuclear threat, the local production, infrastructure and operations were affected. The consequences of the situation were realized globally, with shortages in production particles in the USA and Germany.

However, apart from trade, the impacts of the port on the city's economy prove to be abundant, both direct and indirect. Firstly, the generated income through port employment vitalizes the city's local economy, as it produces dynamic financial flows. Although automation acts as a drawback to employment, the port attracts firms related to the maritime and other industries, producing jobs in an indirect way. However, the trend of specific firms being attracted by the city's competitiveness and not the port itself has also been observed (Merk 2013). These cases highlight the need for collaboration between the port and the city, in order to constitute a competitive urban environment. Nevertheless, the underlying relation between port cities, research and innovation, facilitates the quest for combined port and city competitiveness. According to Merk (2013, p. 28) port regions are home to the highest amount of "patents in technologies that are used in the port sector (constructions, hoisting-lifting-hauling), or important commodities handled in port areas, such as petroleum and food". Nine out of the ten regions with the highest amount of patent applications regarding shipping, hoisting and port related constructions are home to important ports such as Houston, Los Angeles/Long Beach, Tokyo, Oakland and Rotterdam.

2.2 Evolution of the port city, and the relation between port and city

2.2.1 The port city in the pre-industrial and industrial era

> "The port city evolution appears to be gradual rather than linear or chaotic, and in many cases influenced by regional factors or local strategies" (Ducruet & Lee 2006)

Because of the geopolitical and economic importance of ports and due to their connectivity to forelands and hinterlands, many urban settlements were built either next to the water as port cities, either on a protected location with easy access to a port.

Already in the pre-industrial era, the port was more than just a function that secured wealth and employment for the city's population. It was a significant factor for progress and innovation (İleri & Mansel 2012) , triggering the evolution of the whole port-city system (Pesquera & Ruiz 1996). According to the same authors, the characteristics of the spatial relationship between city and port were two: "proximity and immediacy" (Pesquera & Ruiz 1996, 6), highlighting the strong interaction between them. However, the port was the one leading the development of the city, in spatial, social and economic terms.

The industrial revolution changed the equilibrium of the port-city system, although the port was more prominent in the new process as well. Due to industrialisation, ports were required to grow in size and advance technologically. Therefore, they focused on their internal restructure and development, gradually diverging from the urban affairs. On the city side, the economy got revitalised, new activities were introduced, and the city could rely less on the port and more on its own abilities. It moved away from its maritime tradition and culture, a process which also implied significant social changes. Regarding the ports, in many countries they got organized under a national administrative authority, a procedure which completely separated the port from its spatial, urban context. The city could not influence the management of its "own" port anymore, as the port as an entity was increasingly becoming extraneous.

A negative result of the industrial era, related to the social, economic and governmental changes in the port-city system, was the establishment of the environmental degradation perception regarding port cities. Fast growth, lack of adequate time to plan and land use changes at the inner city districts (usually around the port) lead to fast changes and deterioration of the urban environment and the port city premises. (Pesquera & Ruiz 1996)

Therefore, in contrast to what had been happening throughout the centuries, when as also Hoyle mentions, city and port "either developed together or together declined" (1989, p.430), after a certain point this was already not happening anymore. The same author identified the extensive implications that this change had on economy, politics, technological advance and the spatial dimension of port cities. The chronological evolution of port cities and the interaction between city and port as Hoyle presents them are shown in figure 4.

Figure 4: Evolution of the port city (adjusted from: Hoyle 1989)

Stage	Symbol (city / port)	Period	Characteristics
1 Primitive port city		Ancient / medieval to 19th century	Closed spatial and functional association between city and port.
2 Expanding port / city		19th - early 20th century	Rapid commercial / industrial growth forces port to develop beyond city confines with linear quays and break-bulk industries.
3 Modern industrial port / city		mid - 20th century	Industrial groeth (especially oil refining) and introduction of containers / ro - ro require separation / spaces.
4 Retreat from the waterfront		1960's - 1980's	Changes in maritime technology include growth of separate maritime industrial development areas.
5 Redevelopment of the waterfront		1970's - 1990's	Large-scale modern port consumes large areas of land / water space, urban renewal of original core.

2.2.2 Containerization and the relation between port and city

During the last decades, in the era of vast seaborne trade growth, rapidly expanding vessel size, containerization and urbanization, the port has been increasingly expanding and specializing, moving away from the city. An immediate spatial result of urban nature was the creation of a port-city interface of prior port areas like docks which are being redeveloped to receive new, urban uses. This led to the emergence of a tendency to emphasize on the cultural identity of these spaces, as a place that indicates the strong past and competitive character of the city (Mayer, 2003).

Under these changes, port cities have been studied within the spectrum of port performance, urban size and waterfront redevelopment (Ducruet & Lee 2006). Ducruet & Lee utilized two of these characteristics, population and container performance, to build the Relative Concentration Index (RCI): a matrix of port-city interdependence that illustrates the evolution of port cities since 1975, when the processes of globalization and containerization began.

The RCI is an adjusted variation of the index by Vallega (1979) who had expressed the port-city relation through total port throughput and the city's population. The creation of this index in the 70's underlined the increasing attention paid to port performance. However, the replacement of total cargo throughput in the index with container throughput (by Ducruet) emphasizes the establishment of containers as the main unit for trade measurement, and updates the index both numerically and conceptually to address the conditions of the 21st century.

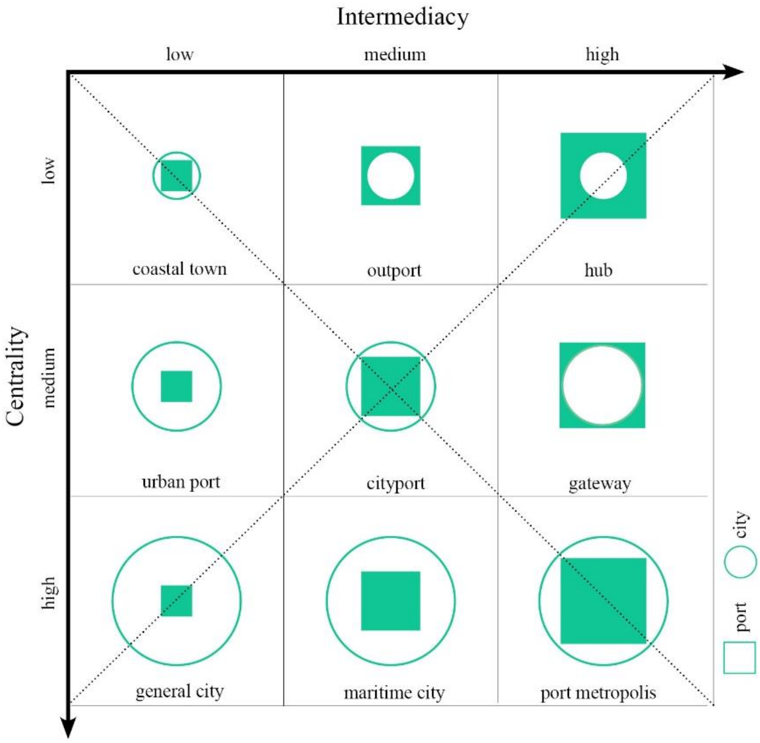
In the RCI, the port city characteristics under consideration are its "centrality" and "intermediacy". Port city centrality regards the position of the port city within shipping networks, describing the amount of direct connections to an international range of countries" (Merk 2013). On the other hand, intermediacy is the function of the port city as a connecting node, as a hub for forelands and hinterlands. According to Ducruet centrality is a characteristic influenced directly by the city, increasing with population growth. On the other hand, intermediacy is a characteristic led by the port's performance and importance as a hub.

Ducruet (2006) subsequently divides the port cities into typologies based on their centrality and intermadiacy scores, expressed by the rate between container throughput and population.

In this way he constructs the Relative Concentration Index, which at the same time identifies nine distinct port city categories: coastal town, outport, hub, urban port, cityport, gateway, general city, maritime city and port metropolis. Each of these categories is characterized by the RCI ratio, and the port city size.

Further on, Ducruet describes the evolution of port cities as continuous transits between the nine typologies, observing trends and exceptions of port city evolution during 1975 - 2005. However, he argues that interpreting the changes of RCI score is a complicated issue, as changes can be the results of various simultaneous phenomena: "urban constraint and spatial growth, port expansion and competition, congestion at the port-city interface, lack of space, logistics costs, uneven industrial growth and location, natural disasters and geopolitical change" (Ducruet & Lee 2006, p.122)

Figure 5: A matrix of port city relationships (adjusted from: Ducruet & Lee 2006)



However, one of the most valuable conclusions of Ducruet, is the observation that port city evolution is gradual, and not linear. Accordingly, the nine identified categories can be divided in three groups of cities, according to the ratio between the port and the city. Although within each group the overall size of the port city varies, the relationship between the two elements remains stable. The two critical RCI values for this division are 0,75 and 1,25. Cities with RCI value between these two values are characterized by a balance, an equilibrium between the port and city functions. However, values higher than 1,25 can be interpreted as "port specialization" and values lower than 0,75 "urban magnitude".

Figure 6: RCI interpretation (adjusted from: Ducruet & Lee 2006)

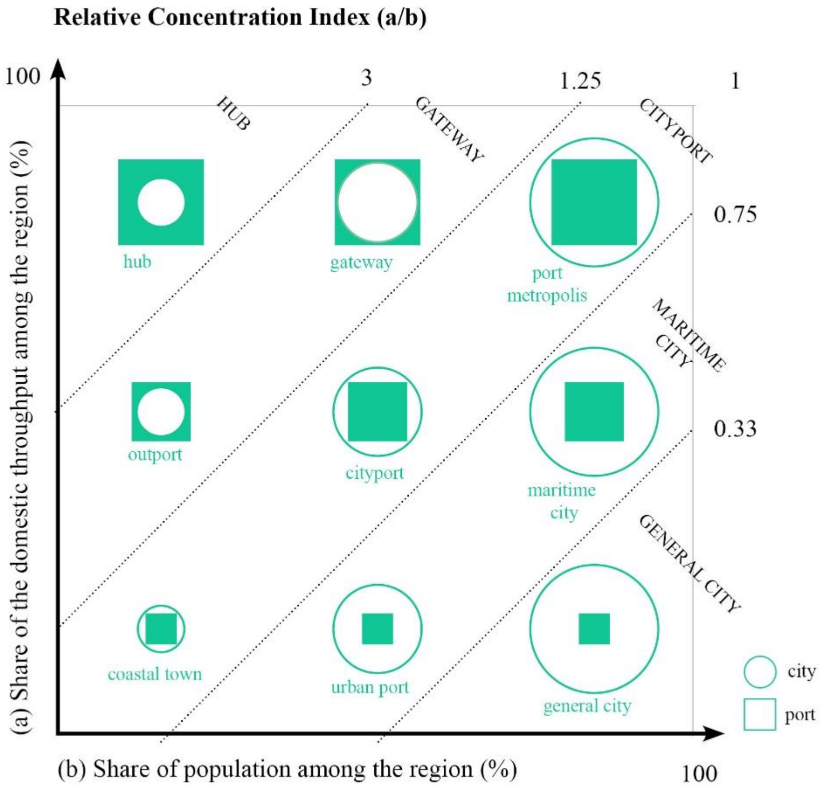
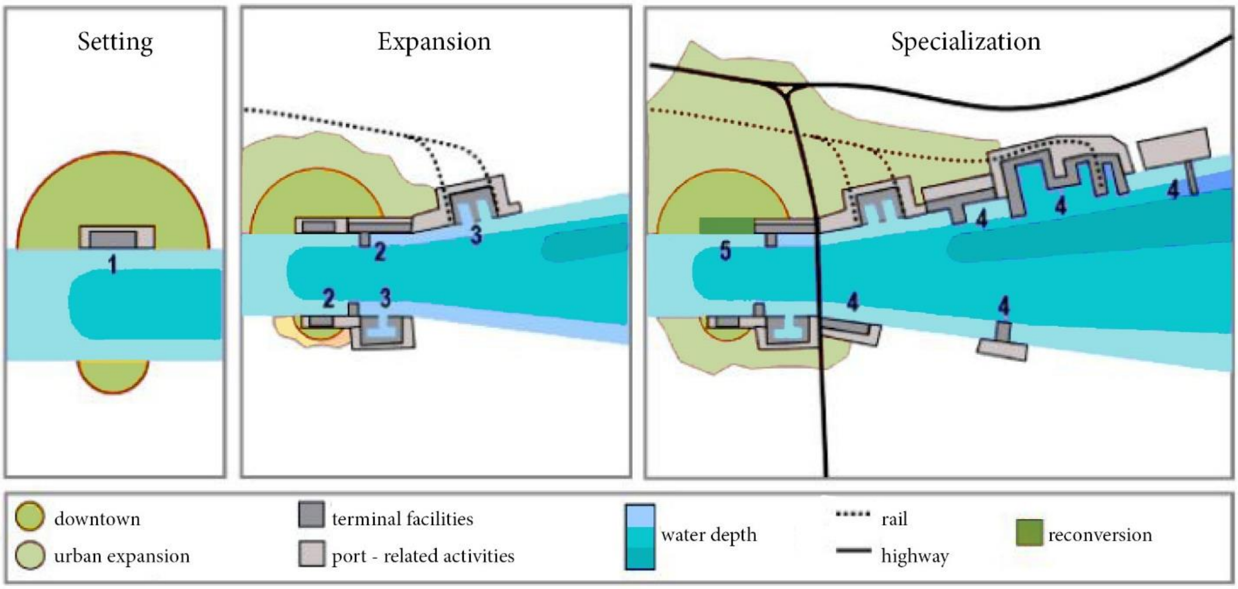


Figure 7: Specialization process of the port city (adjusted from Ducruet 2011)



However, through the report of OECD "The competitiveness of global port cities: synthesis report" (Merk 2013) provides us with a recent overview of the growth trends of ports and cities per continent. According to Merk, Asian port cities (particularly Chinese) have shown notably high, simultaneous growth of population and port volume. The only exception are some Japanese cities with population decline. Regarding North American cities, they have experienced simultaneous growth of the port and the city (examples included in this study: Houston, Seattle, Vancouver) as well as population growth / port decline (examples: Baltimore, Boston, Montreal). In South American port cities, only population increase is observed, while in Europe we can identify all trends: growing city and port (Barcelona), growing city / declining port (Stockholm), stagnating cities/growing ports and stagnating cities/declining ports (Rotterdam and London respectively – not part of this study).

This variety of growth rate patterns is a further indication of the separation between the port and city components, and one of the major arguments for the division between port and city in this study, as well as for the independent research on each part.

2.2.3 Current constrains to the port-city relationship

However, regardless to the growth or decline patterns of the port and the city, the dynamics between them may vary for each case. The relations may be continuous or contemporary, the mutual influence stronger or weaker and they could even be two totally independent entities – at least for a specific period of years.

This ambivalence is the indication of the port city being deemed to a constantly undefined balance between its land-based and its marine functions. (Ducruet & Lee 2006). As has been mentioned, the relation between the two components of the port city has long been the subject of research, from different perspectives. However, most of the studies conclude that a clear explanation and structure for their relation cannot be outlined. One of the reasons is the constantly changing nature of the port-city system, an evolution which has been evenly or abruptly developing throughout the ages. Generally, as Ducruet (2006) explains through the RCI, the overall interdependence between port and city has been since the 70's generally decreasing, challenging port cities through a repeated transformation. The intensity of the port-city relationship decline varies between different world regions, but the overall trend remains the same globally (Ducruet 2007).

A recent example of the determinants that affect their relation can be the steep increase of seaborne trade, with a tripling of cargo volume during the past 30 years (Hanson et al. 2010). Circumstances like this force the equilibrium between port and city functions to become "increasingly unbalanced" as Ducruet & Lee (2006) highlight, resulting to the environmental degradation of port cities as a side effect, and confirming the long established view of port cities as busy, industrialised and polluted. This view is partly supported by recent research (Merk 2013), that identifies the disadvantages of ports as effects that stay localized, and their advantages as spilovers to the regional and global level.

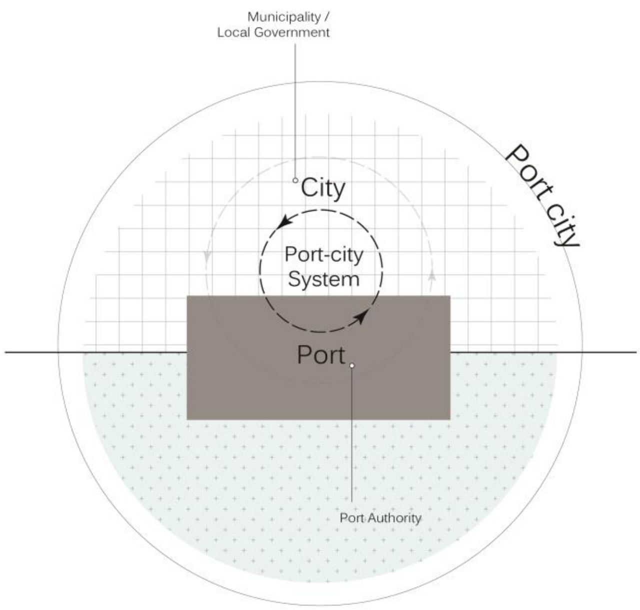
According to Merk (2013) the negative port effects, which affect mostly the port city itself, are mainly related to environmental degradation. They regard water quality through runoff or ballast water discharge, soil acidification, soil erosion, noise pollution, odours, dust particles spread in the atmosphere, waste, threats to the biodiversity, and effects on people's health. Air emissions is disadvantage that poses threats of both local and global scale, as GHG pollutants can impact the climate, on global level. Other port consequences are related to the high urban land percentage occupied by ports, usually incorporating heavy or industrial land uses, the traffic attracted by the port activities, and several social impacts including the requirement for resident relocation or the effect of slums creation.

Due to these negative port impacts, increasing pressure is put on ports from various perspectives. While there is need expand capacity and improve performance, port planning and approval procedures are becoming stricter, the governance arrangements more complex, and the demand for environmental responsibility regarding marine/atmospheric pollution and protection of the biodiversity is growing (Nursey-Bray et al. 2013).

These tensions are a main constraint regarding the port-city relationship, from both sides. However, as the aforementioned issues affect negatively the reputation of the port, in many cases ports have adopted green strategies and are eager to promote a social profile based on sustainability, social awareness and recreation. Many ports publish magazines, launch digital applications, organize public events and communicate extensively through the social media in order to keep the public updated on their environmental concerns and stimulate the port as part of the community.

The attention drawn to port sustainability and the integration with society constitutes an opportunity that port cities can capitalize on, by identifying possibilities of collaboration between the port and the city regarding environmental issues. On a wider perspective, this would benefit both parties in terms of urban competitiveness increase and the upgrade of quality of life. But also regarding the resilience of the port city, it could form the basis for social and institutional resilience, with the aim of facilitating the processes to achieve infrastructural and economic resilience as well (World Bank 2012). Especially in port cities, establishing the foundations for a resilient city could be paramount regarding their exposure to major external risks like CC.

Figure 8: Schematic description of the port city and the port-city system



2.3 Climate change as a challenge of port-cities

2.3.1 Port cities at the forefront of Climate Change

During the last decades, there has globally been increasing awareness about the effects of the two upcoming massive changes that the planet will face because of development and environment exploitation: urbanization and CC. The effects will be intensified by the subsequent rise of the global population: a quintupling of urban population already happened between 1950 and 2011. As a result, big percentages of urban population will be residing in unsuitable areas, with basic services. This will increase their vulnerability to the weather effects which are expected to be exacerbated. (UN HABITAT 2011)

In this contemporary context, apart from the countless benefits that derive from port cities' geographical location and specific dynamics, they inevitably stand on the frontline of the climatic change facing considerable challenges. As mentioned before, according to Nicholls et al (2008) almost 40 million people living in port cities around the world are exposed to a 1 in 100 years flooding event. Moreover, port cities account for 65% of the world's highly populated urban settlements. Predictions indicate that by the 2070's the exposed population will be more than tripled (150 million people). In spite of these massive numbers, not enough practical attention is paid to the preparedness for extreme weather events and the control of human-induced actions with climatic consequences.

2.3.2 Highly exposed port cities

In the research of Hanson et al. (2010) the authors analyse the exposure cost of the 136 most vulnerable port cities worldwide to flooding, according to specific future scenarios. At first, the current exposure of the port cities is calculated in monetary terms (USD) according to the assets exposed to CC within the geographical borders of each urban agglomeration. Afterwards their future exposure (in 2070) is calculated, for different levels of SLR. To calculate the CC exposure, the authors analyse population and economic growth in relation to the SLR, flooding from storm surges, human/induced and natural subsidence or uplift. Among these phenomena, natural subsidence/uplift is identified as the least widespread threat, as it is an issue only for a small number of cities.

On the other hand, human activities in many cases lead to human-induced subsidence. Especially for port cities, where the land of the port is susceptible to erosion as a result of port activities (UNCTAD 2011) and the seabed is constantly being developed by dredging thus disrupting the natural environmental processes and putting pressure on the geographical elements (Becker et al. 2011), the risk of subsidence can be increased. What Hanson et al. (2010) argue is that "collectively, CC and subsidence contribute about one third of the increase in exposure for people and assets under the scenarios considered".

According to the same authors, the most vulnerable cities in terms of population exposed are concentrated in 10 countries, both developing and developed. Most of them (19 out of the 30 most exposed port cities) are located on deltas, a fact that highlights their CC vulnerability: delta cities are located where several bodies of water meet, usually on fertile but low lying grounds (Molenaar et al. 2014). This, along with various recent disasters, is the reason that delta cities have drawn increasing attention as an urban typology that should be studied extensively regarding its CC vulnerability. However, regarding assets exposed, the more vulnerable countries are developing ones regardless of their geographic location.

As a result of the aforementioned risks, the total cost of assets exposed in port cities was 3000 billion USD in 2005, corresponding already to 5% of the global GDP of the year, and is calculated to grow more than eleven times until 2070.

Table 2: Population and assets exposed in 2005 and 2070 (created with information from Hanson et al., 2010)

Year	Population exposed	Assets exposed (USD)
2005	40 million (0,6% of global population)	3000 billion
2070	150 million (5% of global population)	35000 billion

Throughout the study of Hanson et al. (2010) it is highlighted that port cities' exposure does not necessarily lead to high vulnerability, as port cities may have natural defences and constructed adaptation works. However, as the exact consequences of climate extremes cannot be accurately calculated, we cannot be entirely confident of the level of protection that these defences offer. On the other hand, the consequences may not be as severe as the exposure measures indicate. Regardless of these facts, future projections and scenario developments provide useful indications in order to understand the general CC tendencies and realise the need for adaptation. Through better understanding the factors that contribute to higher exposure, and the extent to which the exposure increases even when taking part of the threats into account, it is easier to identify effective adaptation actions and build the city's adaptive capacity.

The ten cities ranking higher in terms of exposure, according to the study conducted by Nicholls et al (2008) are concentrated in three countries (USA, Netherlands, Japan) which bear 60% of the total global port city exposure, and are the following:

Table 3: The ten cities ranking higher in terms of exposure (source: Hanson et al. 2010)

City	Country	Exposure (100-year exposition, million USD)
Miami	USA	532194
Greater New York	USA	824448
New Orleans	USA	323917
Osaka – Kobe	Japan	337354
Tokyo	Japan	276547
Amsterdam	Netherlands	187159
Rotterdam	Netherlands	172316
Nagoya	Japan	175473
Tampa – St Petersburg	USA	111585
Virginia Beach	USA	138390

An important aspect that Hanson et al. (2010) raise, is that by taking into account the time requirements of implementing coastal infrastructure, which is estimated to 30 years, as well as delays in planning and implementation that arise from policy, governance and socioeconomic factors, immediate action is necessary in order to avoid disasters from extreme climate events that can occur by the middle of this century.

To confront these risks and challenges, Hanson et al. suggest that there should be close cooperation of the national government, LGs, stakeholders and decision makers in order for more resources, expertise and engagement to be available for port city adaptation and mitigation action. However, they emphasize the importance of the willingness of governments and authorities to act effectively in order to protect population and infrastructure. This willingness is related to financial issues but is not specifically depended on each country's wealth: a motivated and proactive governing authority can possibly identify and utilize other sources of financing in order to reach its adaptation and mitigation targets.

2.3.3 Cost of adaptation to Climate Change

The cost of adaptation itself is an issue that has been researched, but through many limitations. The cost estimates for adaptation works vary significantly according to the specific conditions under which each project has to be implemented. Therefore, detailed case studies would be the best type of research in order to calculate the cost with confidence. However, there have been attempts to generalize on this issue and provide rough calculations for the investments required for adaptation, already from 1990. The methodologies are based on identifying costs per unit: for example the cost of a "stone protected sea dike" is calculated to be 6.07-11.47 million USD per km (Green & Nicholls 2010). However, the range which is utilized in order to address uncertainties and other characteristics (regarding the previous example, the required height of the dike may vary according to the geographical location and climatic conditions) make the cost calculation a complicated issue.

Regarding the calculated cost, it can be mentioned that Hoozemans et al. calculated the global cost of adapting to SLR to be 1000 billion USD, back in 1993 (Green & Nicholls 2010), while recently the UNFCCC concluded that the total annual investment and financial flows required for CCA in 2030 will vary between 98-342 billion USD (UNFCCC 2007). For this calculation, the life span of the constructions was calculated until 2050 for water supply, and until 2080 for coastal zones measures – indicating the time horizon for which adaptation works should be planned. The wide range of cost is a result of the uncertainties regarding infrastructure investments, as shown in table 4. On the contrary, the investment required for mitigation is estimated to be 200-210 million USD, with a much lesser degree of uncertainty in relation to adaptation estimates.

Table 4: Annual investment and financial flows for CCA in billions of 2005 USD. (source: UNFCCC 2007)

Sector	Global	Developed countries	Developing countries
Agriculture	14	7	7
Water supply	11	2	9
Human health	5	0	5
Coastal protection	11	6	5
Infrastructure	8 to 130	6 to 89	2 to 41
Total	**49 to 171**	**21 to 104**	**28 to 67**

2.3.4 Climate Change impacts on ports

Ports will have to face specific challenges deriving from CC impacts. According to Nursey-Bray et al. (2013) the impacts extend to environmental, economic and social dimensions, and affect directly the communities living near the port, not only the port itself. The five sectors related to ports and affected by CC are identified by Nursey-Bray et al. as the following five:

1. Environment
2. Infrastructure
3. Ports and people
4. Occupational health and safety (OH&S)
5. Supply chain and logistics.

The vulnerability of the port in each of these sectors results to the vulnerability of its surrounding settlement as well.

To begin with, SLR, which is projected to 0,18-0,59m sea level increase in 2100, and flooding as a result of storm surges will expose the port's facilities and infrastructure to material corrosion and degradation because of the increasingly acid sea water and pollutants that will affect the port surfaces. As a consequence, higher maintenance costs, insurance requirements will be a necessity, while OH&S (operational health and safety) issues arise for the port employees, as working in extreme weather conditions involves high risks (Nursey-Bray et al. 2013). Moreover, resulting from less frequent and more intense storms, ports will be confronted with high wind speeds that can be a hurdle for the port's operations, for example cargo handled by cranes.

Regarding port operation, extreme weather effects can have further implications. On one side, the port itself will face the internal challenges of handling cargo. In addition, ships may have to wait outside the port until the extreme weather event is over, causing an operational bottleneck further on. On the other hand, external consequences on infrastructure like road or rail routes could cause disruption of connections to logistic hubs, and cargo could be required to remain at the port for various days.

Another aspect of CC that can affect port operations in unexpected ways is the alteration of navigation routes. The Permanent International Association of Navigation Congresses has already published measures and guidelines under the theme of "Climate Change and Navigation" (PIANC 2010). A recognized example of changing navigation routes is the Northwest Passage, the route connecting the Atlantic and Pacific oceans through the Arctic. As a result of CC the route can be utilized more days per year, introducing possibilities of new ports to be located along the route, and new economies to arise (Naruse 2011). According to UNCTAD (2011) "A fully operating Northern Sea Route would reduce the sailing distance between Rotterdam and Yokohama via the Suez Canal by more than 40 per cent". Moreover, the shipping costs could be reduced by 20%, accounting for 3,5 million USD.

Therefore, anticipated impacts of CC cannot be categorized exactly as positive or negative. They describe new conditions to which port cities need to adapt, in order to protect their assets but also benefit their economies. As Nursey-Bray et al. point out, "The impact of climate change on supply chains is likely to be incremental as these changes occur over time. Port industries should focus on strategically managing the value they deliver through their supply chain to achieve their strategic objectives" (Nursey-Bray et al. 2013)

Table 5: Overview of selected potential Climate Change impacts on ports (adjusted from UNCTAD 2011)

Climate Change factor	**Potential Implications**
Rising Sea Levels - Flooding and inundation - Erosion of coastal areas	- Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) - Increased erosion and sedimentation - Variation in demand for and supply of shipping and port services (e.g. relocating) - Modal shift - Change in the structure and direction of trade (indirectly through impact on agriculture, fishing, energy) - Relocation of business and migration of people, with further economic repercussions (e.g. labour market, closures) - Challenge to service reliability - Increased dredging - Reduced safety (e.g. sailing conditions) - Increased construction, maintenance and replacement costs
Extreme weather conditions - Hurricanes - Storms - Floods - Increased precipitation - Wind	- Damage to infrastructure, equipment and cargo (coastal infrastructure, port-related structures, hinterland connections) - Erosion and sedimentation, subsidence and landslide - Reduced safety (e.g. sailing conditions) - Modal shift - Change in the structure and direction of trade (indirectly through impact on agriculture, fishing, energy) - Relocation of business and migration of people, with further economic repercussions (e.g. labour markets, closures) - Increases in weather-related delays and traffic disruptions - Drainage systems being overloaded causing flooding - Increases in soil moisture can undermine structural integrity of infrastructure - More frequents and extensive emergency evacuations - Reduced clearance under bridges - Increased construction, maintenance and replacement costs - Challenge to service reliability

2.3.3 Climate Change impacts on cities

According to Nursey-Bray et al. (2013) the impacts of CC on cities can vary from physical to social and psychological. As an example regarding physical impacts, the risk of flooding can cause the relocation of settlements and the damages or changes in infrastructure may result in different mobility patterns that affect the function of the city. The effects of climate hazards can be more hurtful, by causing casualties and “psychological trauma” to the people who experienced the hazard (Nursey-Bray et al. 2013, p.1032). Other impacts can be the loss of belongings or homes. In highly developed or more protected cities, like Copenhagen, where loss of lives because of CC is less probable, CC can have impacts on the economy by inducing unemployment because of problems caused to businesses. (Nursey-Bray et al. 2013)

However, the impacts of CC can also be indirect, and not immediately evident. Nursey-Bray et al. (2013) present the example of hurricane Katrina in New Orleans, in 2005. They mention that although the overall costs of the disaster were initially calculated to be 81 billion USD, later the amount reached 130 billion USD, with further yearly requirements of 100 billion USD/year to recover from the damage. (Nursey-Bray et al. 2013). This realization highlights the importance of adaptation measures and increase of adaptive capacity, regardless of their cost.

The situation described concerning New Orleans accentuates also the role of ports during this kind of disasters. During storms or inundation, ports are required to carry humanitarian aid operations, and are one of the main assets that the city depends on. Urban assets with similar function are also the airports (Green & Nicholls 2010; Jacob et al. 2007). Ports, because of CC, are expected to be faced with this challenge even more frequently, even to provide support for disasters that occur in other cities. However, except from humanitarian aid, also support regarding the traded cargo may be required, if a port of the area is constituted unfunctional. For this reason, “the flexibility of supply chain networks and the ability of the port to combine with them is crucial” (Nursey-Bray et al. 2013).

2.4 Port city adaptation response

2.4.1 Ports: types of adaptation actions

The challenges related to CC that ports will have to confront are widely recognised. However, according to a survey carried within American ports, while 81% of American ports identify their CC risk, 31% demonstrate insufficient knowledge regarding its costs and consequences, as well as the extent of the port’s vulnerability. (UNCTAD 2011)

According to Nursey-Bray et al. (2013), the implications of CC on ports will affect initially their regulatory framework. New conditions will require stricter planning regulations regarding coastal development, introduction of advanced environmental specifications, changes to the OH&S framework and increased expenses on infrastructure development. Moreover, insurance will be a major expense, regarding the cost of the CC risks that the port is unable to reduce. As CC is a new topic in the insurance companies’ agenda, its exact costs and conditions cannot be calculated with confidence.

The first action that can be identified to reduce ports’ exposure risk is the creation of breakwaters and barriers to obstruct water from flooding the port. Another obvious option is the retrofitting of existing structures, as to adjust to CC. However, the high cost of these responses can be a deterrent factor for their adoption. Less costly actions can be the introduction of design guidelines and land use control for new buildings and infrastructure, as well as the relocation of activities and operations that occur in risky areas (Nursey-Bray et al. 2013).

Regarding operations, ports should plan according to the global developments of the supply chain networks and CC at the same time, in order to remain competitive. Altering routes and connections to the port, can be a process that requires a considerable amount of investment and collaboration with third parties like the municipal or national government, private companies and funding programs. However, in the long term this process will have a positive impact on the design and modelling of the supply chain and logistics networks that are related to the port – and therefore economic benefits for both the port and the city.

Climate mapping is another sector where the ports can play a crucial role. As ports are located on the edge of cities with high population, they can monitor locations where the impacts of CC will have a major economic and social impact. Aspects that they can monitor are the height of waves, the extent of storm surges, changes in the tilt of tectonic plate and SLR. (Nursey-Bray et al. 2013)

As far as OH&S is concerned, the introduction of design regulations for the port facilities (e.g. elevated floors and office spaces), the installation of early warning systems and the introduction of automation in procedures that involve risks according to the weather conditions are actions that ports can incorporate.

As Nursey-Bray et al. (2013) identified through their survey to Australian ports, many of the adaptation actions are included in risk management processes, and not treated as CCA actions per se by the port managers. As the identification of the threat and the implementation of the actions is what matters, diverging adaptation actions through other sectors should not be a concern. However, this partial approach deprives ports of the opportunity to address the issue holistically and combine actions and investments in the most beneficial manner.

Collaboration not only between the departments of the port but also with external stakeholders can make a substantial difference (Ng et al. 2013)(Ng et al. 2013). This is an obvious conclusion we can make by realising that the jurisdictional limits of the port, are much narrower than its area of interest. A case where this inter-jurisdictional collaboration has been successfully implemented is described by Ng et al., regarding one of the major Australian ports. The port is part of offshore and gas projects, providing insight on issues related to transportation and CC, indicating the role that the port can play as a facilitator of collaborations between industrial and governmental parties.

2.4.2 Cities: types of adaptation actions

Although cities are among the main generators of CC, they are also the entities highly threatened by its impacts. Therefore, LGs play a vital role regarding the mitigation of the impacts of CC at global level, and the adaptation of cities to CC and the new climatic conditions (Aylett 2014). Although a few years ago the engagement of cities to CC used to be focused entirely on mitigation and use of energy, adaptation has gradually received more attention, though still not equal to the attention that is paid to mitigation actions. In a survey recently conducted by ICLEI (Aylett 2014), only 3% of the 350 cities who participated indicated that they have adopted only adaptation actions, as a response to CC. However, 24% of the cities has taken mitigation actions only, while 73% of the cities declared both adaptation and mitigation activity.

A major conclusion of the survey is the tendency of climate-related plans to be integrated in other types of plans and strategies. For this reason, mainstreaming the actions through other municipal activities was a popular tendency. Although the survey results show regional variations, another overall conclusion that can be retrieved is that within the associated stakeholders, civil society groups and residents proved to be the most involved member, actively supporting actions and plans both in their design and their implementation. The private sector shows less involvement than all parties.

The active engagement of residents in adaptation as a local concern, is described in the research of Castán Broto & Bulkeley (2013), who identified the actions that can be taken in cities in the form of "experiments". In this context, urban governance is considered as an instrument through which innovation and various partnerships can be promoted, even under the realization of the future uncertainties they may entail.

However, in the study of Castán Broto & Bulkeley (2013) adaptation is also subordinate to mitigation. Specifically, adaptation is considered as one single action type and is not divided in sectors, as is mitigation in which we can find five different categories of actions. In this context, adaptation is the fourth most popular type of experimental actions identified, accounting for 12% of the responses, after urban infrastructure (32%), built environment (25%) and transport (19%). Mitigation actions related to the urban form and carbon sequestration rank last in the list.

Nevertheless, in the same study it is mentioned that adaptation experiments may rank less due to their frequent lack of "visibility", as many times they can be included in disaster management programmes and be listed under different categories – the same observation that was made regarding port actions and risk management. In the study of Castán Broto & Bulkeley (2013), the adaptation schemes that are identified are: cooling services and designs, measures securing energy and water supply, flood protection, bushfire protection, relocation and zoning policies, blue and green infrastructure, building codes for extreme weather, early warning systems, behavior-based measures.

However, the presence of a wider framework to support also small scale initiatives is essential. Portraying adaptation at the national level, UNFCCC (2007) identifies the following types of adaptation actions: agriculture, forestry and fisheries, water supply, human health, coastal zones, infrastructure and natural ecosystems. Especially regarding coastal zones, which are closely related to port cities, the actions are associated to the prevention of soil erosion, limitation of coastal area development, guidelines for the construction of coastal infrastructure, restoration of beach vegetation and waste management.

Moreover, the importance of incorporating Integrated Coastal Zone Management processes is emphasized, aiming to an integrated approach among the following sectors:

- Engineering of coastal defences and causeways
- Disaster management
- Insurance for extreme events
- Warning systems
- Education and communication
- Planning

2.4.3 Integrated Coastal Zone Management

The Integrated Coastal Zone Management approach was developed after recognizing the upcoming challenges of population increase and climate change, especially regarding coastal areas, in the Earth Summit of Rio de Janeiro in 1992 (Post & Lundin 1996). Based on the realization of the multiple aspects that affect the preservation and protection of the coastal ecosystems and resources, but also on the awareness of their importance, guidelines and cases studies started to be published regarding an integrated approach to manage coastal areas, with the goal of sustainability.

The ICZM approach is structured along three main principles: cooperation between all involved stakeholders, strengthening of management in each of the related sectors, preserving and protecting the ecosystem and natural habitats from unsustainable human activity. However, at the same time ICZM aims at enhancing the economy of the area and utilizing the natural resources in the most efficient manner. According to the principles of ICZM all these aspects are institutionally and legally bound, to ensure the proper implementation of the management schemes and pursue sustainability. This requires also specific spatial boundaries of responsibility and of implementation.

However, the benefits and consequences from coastal interventions are not static but spill over to neighbouring triggering regional or international implications. For this reason, a first step in order to increase awareness and highlight the need of an integrated approach is to make the economic benefits obvious, across the stakeholders of the area. This dissemination of the concept in different groups entails difficulties due to their different nature: national government, agencies and ministries, local government, research institutions, coastal stakeholders, general public (Post & Lundin 1996).

From this description the common ground on which climate change adaptation of coastal areas and ICZM are evolving on is obvious. The ICZM approach underlines the cooperation and collaboration required between different scales and levels of government, management and action, which is exactly what most of the authors in the revised literature conclude to, regarding CCA. However, throughout the literature on ICZM case studies, there are also many records of unsuccessful implementations due to the failure to achieve a truly integrated approach from all aspects, which may lead to further or bigger problems. A possible reason for that may be the lack of updated guidelines and theoretical background on the subject, as most studies focus on experimental research focused on implementation (Farhan & Lim 2013). However, the positive relation between adaptive management of natural resources and climate change resilience remains undisputable (Tompkins & Adger 2001).

2.4.4 Adaptation deficit and maladaptation

Resulting from the literature review, it is widely accepted that CCA is an issue of vital importance for ports and cities, "one of the greatest challenges of our time" (UNCTAD 2011, p.4) which requires the involvement of all the sectors that are related to its heterogeneous nature (UNFCCC 2007). The current, general adaptive capacity of the planet is described by UNFCCC (2007, p.99) as an "adaptation deficit". This reasons for this deficit are the consequences of extreme weather events, which have been increasing rapidly during the last 50 years. According to the UNFCCC (2007), evidence shows that this deficit is still growing as a combined effect of urbanization, CC and lack of adequate responses: "Societies are becoming less well adapted to current climate. Such a process of development has been called "maladaptation" (UNFCCC 2007, p.99)

To effectively confront CC risk, UNFCCC identifies three ways of action:

- Protection, achieved by reducing the risk of the climate event's consequences

- Accommodation, through building the resilience of society to the effects of disasters

- Retreat, achieved through increasing the adaptive capacity of a city to an imminent threat.

However, regarding highly exposed environments like port cities, these three steps of action should be taken simultaneously. Taking into account the long life span of port infrastructure, "protection" has to be already included in current plans, in order to correspond to the future requirements. At the same time, cities have to critically assess whether they will have to accommodate or retreat from CC hazards in the near future, and take relevant and effective action. In accordance with UNCTAD (2011), "today's decisions may determine future vulnerability to CC."

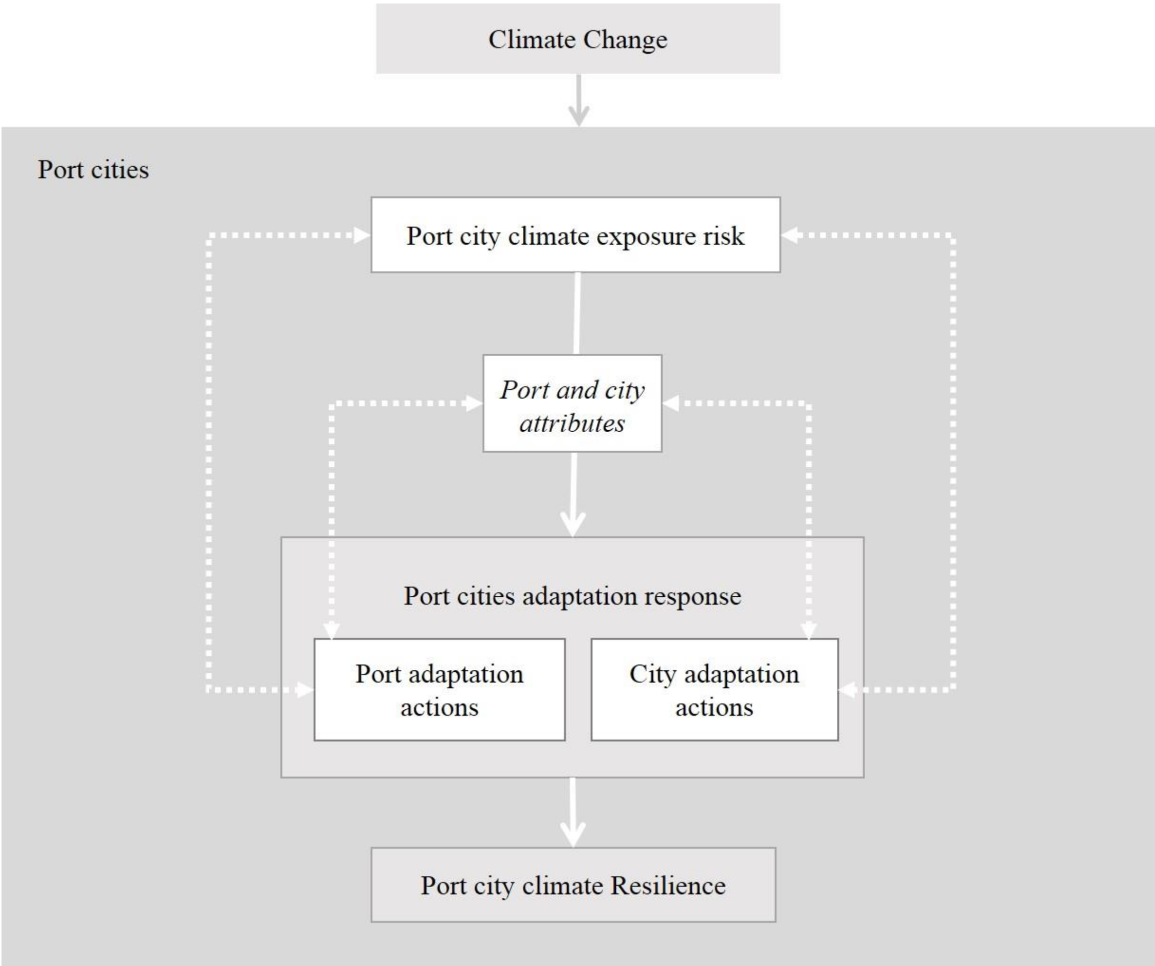
> "Effective adaptation action at the local level requires a good understanding of relevant climatic impacts and likely vulnerabilities. This information, important and urgently needed for the purposes of both risk assessment and planning, is at present not readily and widely available."
>
> (UNCTAD 2011)

2.5 Conceptual framework

In this perspective, the aim of this study is to identify the actions through which port cities, highly exposed to CC, are acting to increase their adaptive capacity and prepare themselves to respond to CC. Due to the aforementioned dual nature of the port city, and the separation of its components, the port and the city will be examined separately, as two different entities. However, as it has been identified that there is a strong connection between them and they are not autonomous, this relation will also be explored, in relation to their climate risk and the adaptation actions they have adopted. Specifically, the types of actions that the port and the city adopt will be related to their respective attributes, and the relation between these attributes and the adoption of adaptation actions will be explored.

The ultimate goal of this research is to map the adaptation activity of port cities on the global level, and identify how the port city characteristics are related to the adoption of the actions. In this context, the CC challenge is recognized more as an opportunity for port cities, a tangible reason to investigate ways of increasing port city capacity and build institutional, social, infrastructural and economic resilience to CC.

Figure 9: Conceptual framework



Chapter 3: Research Design and Methods

3.1 Revised research questions

The specific goals of the research, as mentioned before, are:

1. to identify the climate adaptation actions that LGs and PAs take, and organize them in categories according to the reviewed literature,
2. to relate the attributes of the ports and cities to their climate exposure and adaptation response,
3. to identify the relation between the port and the city and examine the types of climate adaptation actions they adopt from the perspective of this relation.

3.2 Research approach and design

The research aims at initially gathering data on port adaptation actions, for which there does not exist any registry with recorded data on global scale. This information will be examined along with the adaptation actions of the LGs and numerous attributes of the port and the city, with the aim of reaching conclusions regarding the correlations between the various variables.

The majority of the information that will be used in the research comprises of quantitative data (such as exposure risk in USD), and qualitative data, for example the various typologies of port cities, adaptation actions and the categories into which they are organized.

The research is on a wide extent rendered according to the availability of data on the port city subject. As it has been highlighted in the literature review, the data available on ports / port cities are limited and very specific – particularly concerning CC. Apart from the secondary data previously available, primary data were collected regarding the information that is not available from secondary sources, but also in order to validate secondary information. Both primary and secondary data were collected using online sources and published articles / reports.

3.3 Operationalization: variables and indicators

The two main concepts analysed in the research are climate change resilience and port cities. The concepts are further divided in variables and indicators. The concept of CC resilience is described by the variables "port city climate exposure risk" and "port city adaptation response". The concept port city itself is divided in the variables "port attributes", "city attributes" and "port-city relationship". Following this first divisions, the variables are further subdivided in indicators, as shown in table 6.

Table 6: Operationalization of the conceptual framework

Concept	Variables	Indicators	Values / Units
Climate change resilience	Port city climate exposure risk	Mean annual loss for 20 cm SLR and subsidence, without adaptation	Million USD
	Port city adaptation response	Port adaptation actions types	Technological
			Engineering
			Design & maintenance
			Planning
			Climate mapping & risk assessment
			Management systems
			Policy & action plans
		City adaptation actions types	Action plan / report
			Coastal zones & marine ecosystems
			Early warning systems & disaster management
			Terrestrial ecosystems
			Infrastructure
			Water resources
			Food security
			Health
Port city	Port attributes	Port size	Small
			Medium
			Large
			Very large
		Formation way	Natural
			Artificial
		Authority type	Public: national
			Public: regional
			Public: municipal
			Public – private
			Private
			Landlord port type management
		Port performance	TEUs handled
	City attributes	Population Density	Population / sqkm
		Welfare	City GDP per capita
		Location	Delta city
			Coastal city
	Port-city relationship	Relative Concentration Index	Ratio: container throughput / population
		Collaboration to adaptation	Responses (yes/no) to questionnaire

3.4 Research methods

The research was conducted as combination of a survey and a desk study research due to the large number of port cities studied, as well as the time and cost efficiency requirements. The methods utilized were chosen so as to support the generalization of the conclusions, a fundamental inquiry since the study is conducted on a global scale.

The survey part of the research regarded the identification of the ports adaptation actions by collecting primary data from the PAs. The desk research concerned the data collection on port city exposure and relationship, as well as the port and city attributes and the adaptation actions adopted by the municipalities.

Apart from advantages, the chosen research methods expose the study to challenges such as

- restrictions regarding the cities that can be included in the research,

- restrictions regarding the measurement units that could be used due to data availability,

- missing data entries in the databases,

- lack of data reliability resulting in constant need of triangulation,

- data published in various languages,

- variety of data collection timeframes for different variables because of variety of sources,

- difficulty of conducting the survey in the native language of every country, and therefore possibility of different interpretations of the questions,

- dependence on the accessibility and availability of specific persons within the PAs and LGs to respond and share information.

In some cases, these challenges caused problems like restricted access to contacts, responses and data, as well as uncertainty for the retrieved information, for example when the responses of two different persons from the same PA were not the same. These inconsistencies were met with additional data collection from independent / third sources and triangulation as well.

3.5 Data collection methods

Deriving from the literature review and as has been already mentioned before, the research is dividing the port city concept to its two components (port and city) and their relationship. This structure, along with the data availability on each component influence the choices on data collection methods and instruments as well.

Regarding the data on the "city" component of port cities, several secondary sources are used to collect the required data. Specifically, the information on the climate adaptation actions of the LGs is retrieved from the online carbon*n* Cities Climate Registry (citiesclimateregistry.com) which is operated by the Bonn Center for Local Climate Action and Reporting and contains data uploaded voluntarily from 435 cities in 44 countries globally. The categories in which the adaptation actions are organized for further analysis are also based on the sectors of actions as they are identified by the cCCR. When it is required (for example in cases of non-classified actions) the action documents and action plans mentioned or uploaded in the database will be studied, to validate the information collected. The cities density which is used as a variable in the research also derives from the carbon*n* registry. Regarding the city

GDP per capita, the data was retrieved from the Brookings website online interactive map "Global Metro Monitor" (Brookings Institute 2014), representing the year 2011-2012. The information for the categorisation between delta and non-delta cities occurs from multiple online sources including the cCCR, the Connecting Delta Cities initiative, part of the C40 cities network (Connecting Delta Cities 2014) and the Delta Alliance (Delta Alliance 2014).

Previous studies on port cities are utilized to acquire secondary data concerning the port cities' exposure to CC and the port-city relationship. Specifically, the exposure of port cities is retrieved by the database published by Hanson at al. in 2010, the link to which is provided in their study *"A global ranking of port cities with high exposure to climate extremes"*. The database provides various risk and exposure indicators, for different future scenarios. However, the indicator that is used in this study is the mean annual loss in million USD, under the scenario that assumes 20cm increase in sea level and subsidence, without any adaptation measures taken into account for the calculations.

Regarding the port-city relationship data (as described by the RCI indicator), the article by César Ducruet *"Frontline soldiers of globalization: port-city evolution and regional competition"* published in 2006, presents a time series database of the five-year period RCI calculations of the world's most populated port cities between the years 1970-2005. The entries used in this study are the most recent RCI entries, namely the RCI entries of 2005 regarding the selected sample. From this study and the respective entries, apart from the RCI in a numerical format, we can also identify the typology of each port city as it derives from the categorization that Ducruet proposes.

As far as the ports adaptation actions are concerned, the availability of secondary data is scarce. Therefore, a questionnaire was created in order to collect primary data on the current adaptation actions of the 37 studied ports on a consistent and comparable basis. The questions of the questionnaire regarded the adaptation actions divided in categories which derive from the studied literature, as well as the PA typology.

Specifically, the PA typologies identified are adopted from the *"Survey on environmental monitoring requirements of European ports."* (Darbra et al. 2009). The adaptation actions and categorization derive from the following four studies:

- Becker et al., 2014. *A note on climate change adaptation for seaports: A challenge for global ports, a challenge for global society,*
- Nursey-Bray et al., 2013. *Vulnerabilities and adaptation of ports to climate change,*
- Ng et al., 2013. *Climate change and the adaptation strategies of ports: the Australian experiences.*
- Scott et al., 2008. *Climate change adaptation guidelines for ports*.

The questionnaire was administered online through the Google Forms platform and was available to the PAs in two languages: English and Spanish (for the three Spanish-speaking countries: Spain, Peru and Argentina). A partial translation for the introductory/explanatory text was also done in Japanese. It was sent to the PAs principally by email, using addresses gathered from the ports' websites, the World Port Source database (Source 2014), and Lloyd's List directory (Lloyd's list 2014) but also from personal contacts and the IHS alumni network. However, in order to increase the response rate, people within the environmental departments of the PAs were also contacted by phone and through the social media (Twitter, Facebook, LinkedIn).

Regarding the rest of the information on ports (like size, and process of formation), they were retrieved from the ports' websites, searches on the internet and published papers, and the World Port Source database. The port performance in TEUs main source was the publication Top 100 Container Ports 2013 (Containerization International 2014). Although the initial purpose was to use total cargo to measure ports' performance, the data was not possible to gather for the 37 ports in the study. Therefore, in the context of containerization and due to the global level on which the research is conducted, measuring the performance in TEUs, a global measurement unit widely acceptable was a valid option for which all the required data was available. The fact that the same unit was used by Ducruet & Lee (2006) in a study that plays major role in this research supported this decision.

3.6 Sample size and selection

The port cities sample for this study comprises of the 40 port cities for which all the required information was available from the databases. Therefore the sampling is purposive, selecting the port cities that constitute the mutual entries of the three main data sources:

1. carbon*n* Cities Climate Registry (www.citiesclimateregistry.com)
2. (Hanson et al. 2010). *A global ranking of port cities with high exposure to climate extremes.*
3. Ducruet & Lee, 2006. *Frontline soldiers of globalization: Port–city evolution and regional competition.*

The following figure (figure 10) visualizes the selection process and indicates the data that can be retrieved from each source, and table 7 presents the selected cities.

Figure 10: The selection process for the selected port cities

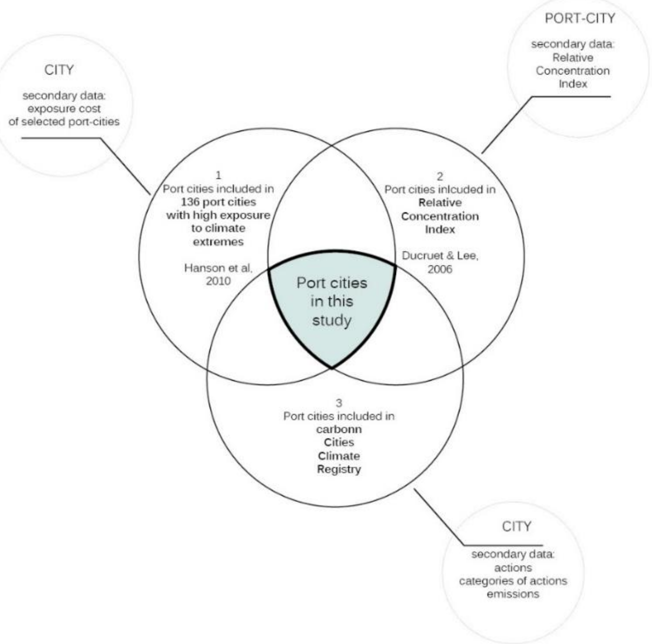


Table 7: The port cities studied in the research

	Port city	Country	Continent
1	Baltimore Maryland	USA	North America
2	Barcelona	Spain	Europe
3	Boston Massachusetts	USA	North America
4	Buenos Aires	Argentina	South America
5	Cape Town	South Africa	Africa
6	Cochin (Kochi)	India	Asia
7	Copenhagen	Denmark	Europe
8	Dar es Salaam	Tanzania	Africa
9	Durban	South Africa	Africa
10	Fortaleza (Ceara)	Brazil	South America
11	Hiroshima	Japan	Asia
12	Houston Texas	USA	North America
13	Istanbul	Turkey	Asia
14	Keelung	Taiwan	Asia
15	Kobe	Japan	Asia
16	Lima	Peru	South America
17	Lisbon	Portugal	Europe
18	Long Beach California	USA	North America
19	Los Angeles California	USA	North America
20	Malmo	Sweden	Europe
21	Melbourne	Australia	Australia
22	Miami Florida	USA	North America
23	Montreal	Canada	North America
24	Nagoya	Japan	Asia
25	New Orleans Louisiana	USA	North America
26	New Taipei	Taiwan	Asia
27	Oakland California	USA	North America
28	Osaka	Japan	Asia
29	Portland Oregon	USA	North America
30	Porto Alegre	Brazil	South America
31	Recife	Brazil	South America
32	Rio de Janeiro	Brazil	South America
33	San Fransisco California	USA	North America
34	Seattle Washington	USA	North America
35	Stockholm	Sweden	Europe
36	Tacoma Washington	USA	North America
37	Taipei	Taiwan	Asia
38	Tokyo	Japan	Asia
39	Vancouver	Canada	North America
40	Yokohama	Japan	Asia

However, it is important to mention that although the total number of entries in the sample is 40, this number represents the amount of municipalities that are related to the studied “port cities”, which are actually 37. As an example, Taipei and New Taipei do not have a port, as the port is part of the Municipality of Keelung. However, Hanson et al. (2010) refer to the port city as Taipei (as they study the urban agglomeration), and Ducruet and Lee (2006) as Keelung-Taipei. Spatially, the Municipality of Taipei is enclosed in the Municipality of New Taipei, which is surrounding Keelung, For this reason, in this specific case, Taipei, New Taipei and Keelung are all included in the research, for the additional reason that in cCCR there is no entry for Keelung, but for Taipei and New Taipei.

The third municipality which is not considered a port for similar reasons is San Fransisco. Both Hanson and Ducruet refer to the port city as Oakland-San Fransisco. However, although both municipalities are included in cCCR, the port of San Fransisco was impossible to identify and contact, therefore is not under consideration as a port in this research. More detailed information on how each city appears in the different databases used, and also the availability of data in the datasets can be found in Annex 1.

Moreover, as a result of the research methods utilised, the analysis part regarding the ports, their characteristics and adaptation actions is based on the responses to the questionnaire that was sent to the 37 Port Authorities. The responses received were 14 (37% response rate) thus this is the port population that will be finally analysed, when the information gathered through this questionnaire is examined. All the other questions will be answered in relation to the full sample of 40 port cities.

3.7 Validity and reliability

Regarding the internal validity of the research, it is achieved by testing hypotheses and relations between variables that were introduced at the beginning of the research, from the literature review and the specific research objectives. The indicators used to describe the concepts of port city and CC resilience also derive from published sources in the literature review. Moreover, the selected sample is not a convenience but a purposive sample as the overlapped entries of three different port city sets, from three different sources. This is a main reason for the data collection constraints mentioned before. However, the sampling method is also a way to ensure that selection bias is limited and that the sample can be considered representative. This characteristic supports the external validity of the research as well, and allows the findings to be generalized, despite the small sample size in relation to the much larger number of port cities worldwide.

As far as the validity of the instrument (questionnaire) used is concerned, its content covers all the adaptation sectors and actions that were identified by multiple sources during literature review. Regarding the criterion-related and construct validity, the questions are divided in actions typologies groups, and ports are studied in terms of the adoption of types of actions and not total number of actions. Therefore, the questionnaire can differentiate between ports that adopt actions of different sectors, and would not identify as equal responses that end up in the same number of actions answered with “yes” when the actions are not under the same sectors.

As a result, the questionnaire can be utilized with confidence to collect information regarding the requirements to answer the research question, such as the number of actions of each type per port. A weakness of the questionnaire however, is the possibility of some actions to be categorized in more than one typologies. In these cases, the actions were adjusted and categorized under the typology that was more suitable according to the verbal expression of the action. From the aforementioned perspectives, the proposed framework solidly reflects the scope of the research.

Concerning the reliability of the research, most of the data analysed is secondary data collected from open sources or published documents. Specifically, apart from the studies published in academic journals, the main source of secondary data used in this research is retrieved from the cCCR registry. Although the cCCR is a voluntary initiative and the information it provides is not verified (Moncuit 2013) it is considered a trustworthy source since it is an initiative that is related to renown organizations and institutions like the World Mayors Summit on Climate in Mexico City, ICLEI – Local Governments for Sustainability, United Cities and LGs and operated by the Bonn Center for Local Climate Action and Reporting – carbon*n*®.

However, partial lack of data in several entries was noticed in the cCCR registry. In these cases, data was collected from different sources such as the municipalities' websites and climate strategies/action plan documents. Additionally, emails were sent to the LGs in order to confirm the published information. However, due to the low response rate this triangulation method could not be applied to the whole sample, but to limited cases.

3.8 Data analysis methods

The collected data will be analysed using statistical software (Microsoft Excel and SPSS). The relations between the variables will be explored and analysed, structured according to the initial hypotheses. Gradually, all the research objectives will be addressed in order to conclude by answering the overall research question.

The data analysis method utilized will be the identification of the correlation and the statistical significance between pairs of variables. Before the data is analysed, it will be tested with statistical tests corresponding to the type and amount of variables in each hypothesis.

The concepts, variables and relations that will be correlated regarding the port and the city are illustrated in figures 11 and 12 respectively.

Figure 11: Port attributes and the port actions to which they will be related to

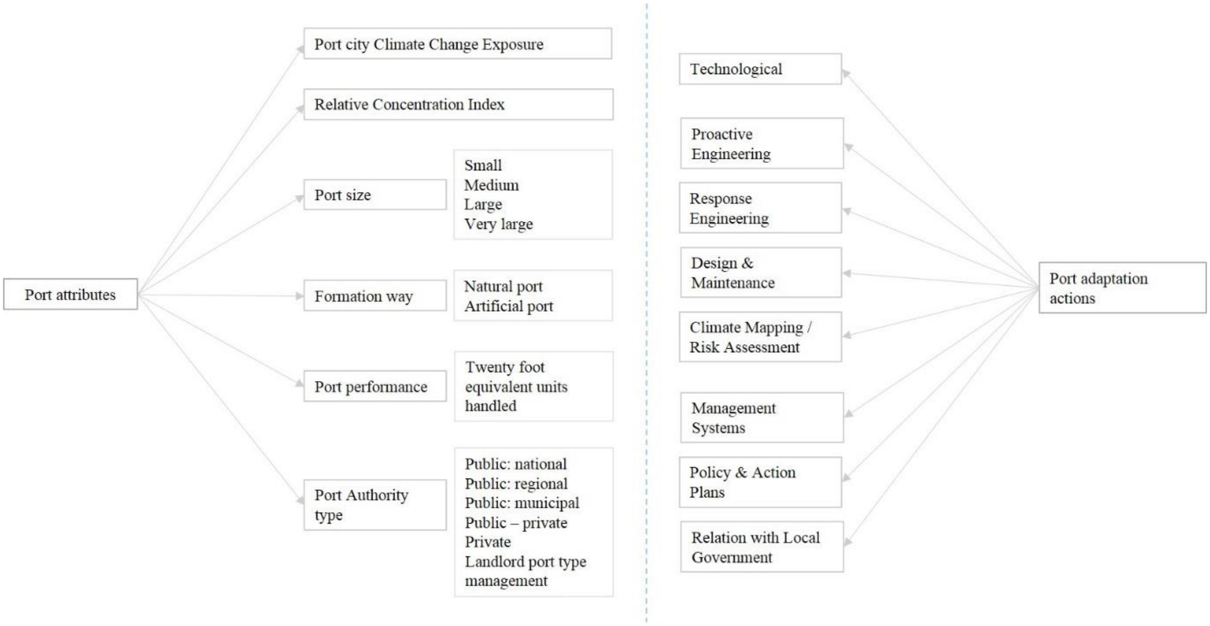
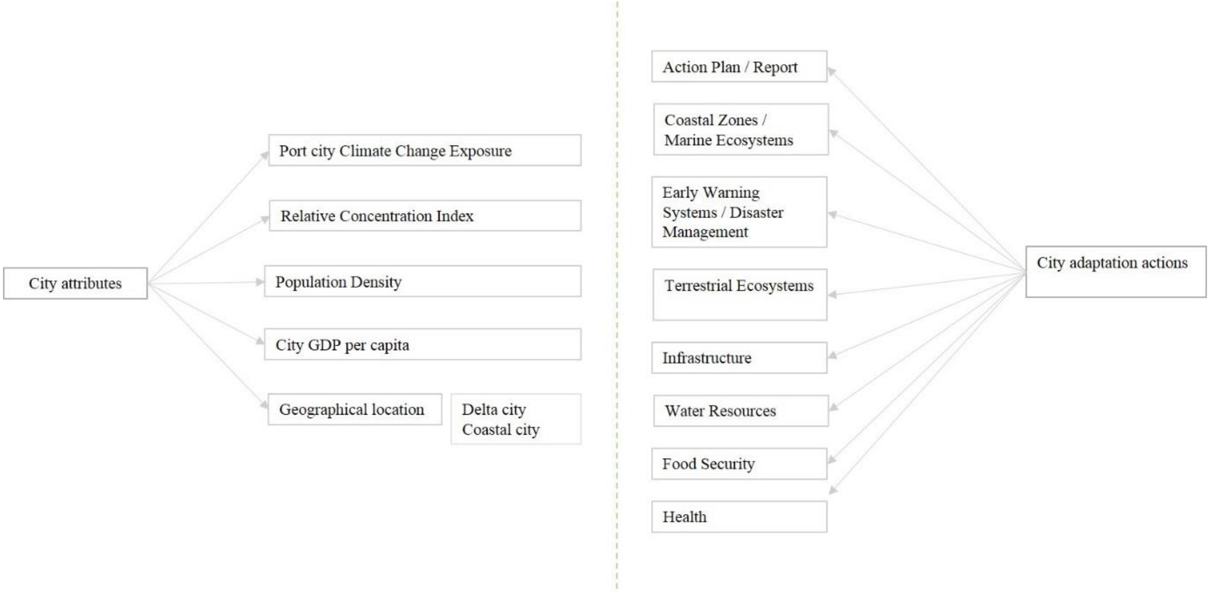


Figure 12: City attributes and the city actions to which they will be related to



Chapter 4: Data analysis

4.1 The port cities sample

4.1.1 Geographical location and characteristics of selected port cities

The port cities examined in this research showcase ten countries in total. The countries which are represented by the largest number of port cities are USA and Japan, which are also the countries with the highest estimated value of exposed assets in 2070 (Hanson et al. 2010). Only Brazil and Taiwan are represented by more than two cities, while Sweden, South Africa and Canada are part of the sample with two cities per country, and for the rest of the countries there is only one port city per country, within the sample that will be analyzed. As a result, 34% of the sample are North American port cities, 26% Asian, 16% South American, 13% European, 8% African and 3% Australian port cities. Regarding the development level of the port cities in this study, 68% of them are in very highly developed countries, 16% in highly developed, and only the remaining 16% in countries of medium or low development, according to the Human Development Report 2014 (UNDP 2014).

Chart 1: Number of examined port cities, per country

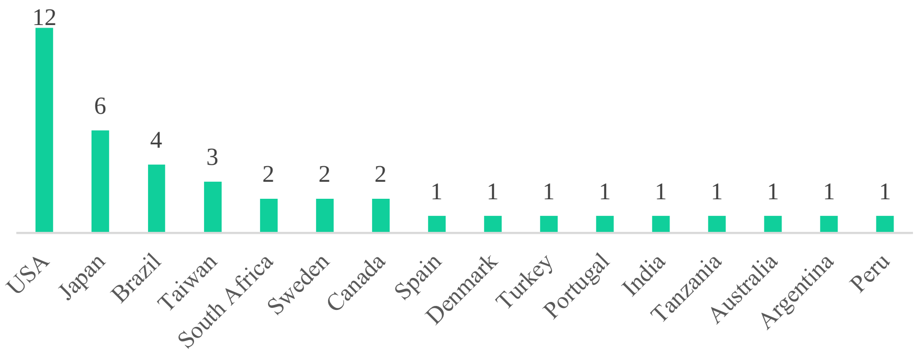
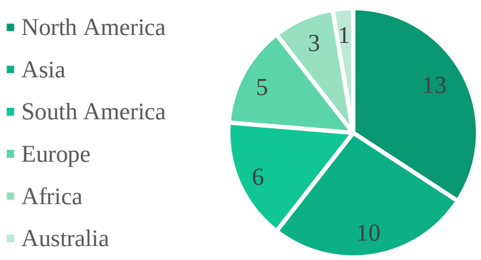
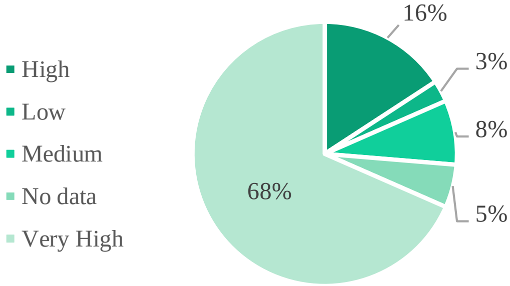


Chart 2: Selected port cities, per continent / Chart 3: Development level of examined port cities





The vast majority of the ports in the selected cities (69%) are of very large and large size, while 23% are medium sized and only 8% are small ports. Half of the ports rank among the top 100 container ports (Containerization International 2014) with the busiest one in the sample, Los Angeles, ranking 16th among the 100. It is worth mentioning that the second busiest port of the sample is the one of Long Beach (ranking 22nd among the top 100 ports), which is adjacent to the port of Los Angeles. The TEUs handled by the Los Angeles/Long Beach complex (14.123.376 TEUs) are more than three times the container cargo handled by the third busiest port in the selection, which is Tokyo, ranking 28th globally with 4.751.653 TEUs. Regarding the smallest ports in the sample, they are Fortaleza (Brazil), Stockholm (Sweden), Lisbon (Portugal) and Recife (Brazil), with Recife handling only 2149 TEUs.

Table 8: The ten busiest ports in this research

Port	TEUs handled in 2012	Top 100 container ports 2013 ranking
Los Angeles California	8077714	16
Long Beach California	6045662	22
Tokyo	4751653	28
Istanbul	3097464	42
Vancouver	2713160	48
Keelung	2704730	49
Nagoya	2655225	50
Kobe	2567540	52
Melbourne	2547623	53
Durban	2529404	55

As far as the size of the cities is concerned, the population numbers vary greatly, between 13.185.502 (Tokyo Metropolitan) and 93.625 inhabitants (Municipality of Melbourne). This is a result of the selection process as well, as the areas under study depend on the local authority which presents its adaptation actions in the cCCR. For example, regarding Barcelona, the Barcelona Metropolitan Area Authority is the authority adopting the actions mentioned in the cCCR (with population of 5.529.099), while in Melbourne only the Municipality of Melbourne, one of the 31 municipalities of the metropolitan area, is mentioned – therefore the population is as low as 93.625 inhabitants. Using these population measurements, the five largest municipalities within the 40 in the sample, are Tokyo, Istanbul, Lima, Rio de Janeiro and Barcelona. The five smallest ones are Oakland, New Orleans, Malmo, Tacoma, and Melbourne. However, regarding the cities' density, which is related to the adaptation actions as a city attribute in this research, neither the largest nor the smallest cities of the sample are the densest ones (table 11).

Table 9: The five largest municipalities in the sample

Municipality	Country	Population
Tokyo	Japan	13185502
Istanbul	Turkey	12915158
Lima	Peru	7605742
Rio de Janeiro	Brazil	6429923
Barcelona	Spain	5529099

Table 10: The five smallest municipalities in the sample

Municipality	Country	Population
Oakland California	USA	406253
New Orleans Louisiana	USA	378715
Malmo	Sweden	280415
Tacoma Washington	USA	198397
Melbourne	Australia	93625

Table 11: The ten densest cities in the sample

City	Country	Population density (pop / sqkm)	Population
New Taipei	Taiwan	15200,0	3893740
Taipei	Taiwan	15200,0	2693672
Buenos Aires	Argentina	14279,4	2890151
Osaka	Japan	11836,0	2666371
Fortaleza (Ceara)	Brazil	11462,7	3597000
Keelung	Taiwan	9627,8	2618772
Malmo	Sweden	9460,0	280415
Yokohama	Japan	8500,0	3697894
Lisbon	Portugal	7457,9	547631
Recife	Brazil	7133,2	1537704

4.1.2 Exposure of selected port cities

As far as the exposure of the cities in the research is concerned, the values are adopted by the previous research of Hanson et al. (2010) as has been already mentioned. However, due to differences in the area and population assumptions, in some cases the values have been adjusted to the area under study in this research. Specifically, in cases like Taipei, which is considered one single agglomeration by Hanson et al. as was aforementioned, the exposure risk has been divided between Keelung, Taipei and New Taipei, in proportion to the area coverage of each municipality. This method was preferred to the consideration of population, as the results of the study of Hanson et al. are principally geographically based, and additionally, regarding other aspects (like the socioeconomic characteristics) the differences between the respective municipalities are not as significant as their land coverage differences.

As has already been mentioned, the most exposed port cities of the research are concentrated in USA and Japan, with the exception of Vancouver in Canada. The densest cities are not within the most exposed ones. However, Tokyo and Los Angeles are among the most exposed and populated port cities, with two of the biggest and busiest ports at the same time.

Table 12: The ten most exposed port cities (source: Hanson et al., 2010)

Port city	Country	Exposure (mean annual loss in million USD)
New Orleans Louisiana	USA	161141
Kobe	Japan	84968
Osaka	Japan	84968
Tokyo	Japan	67958
Nagoya	Japan	57954
Vancouver	Canada	20765
Hiroshima	Japan	9456
Long Beach California	USA	9427
Los Angeles California	USA	9427
Oakland California	USA	7834

4.1.3 RCI of selected port cities

During the analysis of the importance and meaning of the RCI values in the literature review, it has been mentioned that the higher the RCI value, the stronger the dependence of the city on the port. Therefore, RCI values between 0,75-1,25 show a balance between the port and the city functions, while higher values express the prevalence of the port, and lower the predominance of the city. The more the difference from 0,75 or 1,25 the higher the imbalance and the lower the mutual importance regarding the port and the city as separate entities. In general, the highest values identified by Ducruet & Lee (2006) is 7,11 for Colombo (Sri Lanka), 5.99 for Kaohsiung (Taiwan) and 5,35 for Hong Kong. Rotterdam, the busiest European port, scores 4,07.

In comparison to these measurements, the RCI scores of the sample are comparatively low, with only Durban indicating a value higher than 2. However, this proves to be an overall high/low RCI value proportion similar to the proportion of the full index by Ducruet.

With the exception of Durban, the port cities with the highest RCI in the sample are all North American, as we can see in table 13. Moreover, from the same table we observe that a high RCI value does not imply higher port performance, as it describes the inner equilibrium of the port city. For example, we can see that Miami has a lower TEU performance than the previous and the next port cities, when ranked according to descending RCI order. Similarly we see that Seattle and Tacoma, or Los Angeles and Long Beach, which are considered as one single urban agglomeration by Ducruet & Lee and therefore they have the same RCI value, have indeed different TEU performances when they are considered as separate ports.

Table 13: The ten port cities with the higher RCI and their TEU performance

Port city	RCI	TEUs 2012
Durban	2,23	2529404
Seattle Washington	1,67	1885680
Tacoma Washington	1,67	1711133
Miami Florida	1,47	909197
Vancouver	1,4	2713160
Long Beach California	1,38	6045662
Los Angeles California	1,38	8077714
Montreal	1,27	1375327
Houston Texas	1,21	1922529
New Orleans Louisiana	1,19	464834

Similarly, in the next table we can see that the busiest ports (ranked according to the TEUs handled in 2012) show a wide variety regarding their RCI values, with Tokyo scoring only 0,28 directly after 1,38 of Los Angeles/Long Beach. Therefore, we understand that although Tokyo is home to a very busy port, the city itself functions almost entirely separately, as the interdependence of the City of Tokyo and its port is very low. Regarding Los Angeles and Long Beach, by observing these values we can assume that although the ports are very busy, the port city as a whole functions in a balance between the two elements as the RCI value is slightly higher that the ideal 1,25.

Table 14: The ten port cities with the busiest ports (in 2012) and RCI scores

Port city	RCI	TEUs 2012
Los Angeles California	1,38	8077714
Long Beach California	1,38	6045662
Tokyo	0,28	4751653
Istanbul	0,06	3097464
Vancouver	1,4	2713160
Keelung	0,43	2704730
Nagoya	0,42	2655225
Kobe	0,37	2567540
Melbourne	1,11	2547623
Durban	2,23	2529404

Similarly, from table 15 we can see that the TEUs handled by the cities with the lowest RCI vary greatly and can also be very high. Specifically, the smallest RCI value of this research (0,06) belongs to Istanbul, which is the 4th busiest port of the sample.

Table 15: The ten port cities with the lowest interdependence between port and city and the TEUs of 2102

Port city	RCI	TEUs 2012
Portland Oregon	0,26	183202
Recife	0,25	2149
Malmo	0,22	475000
Copenhagen	0,22	148000
Fortaleza (Ceara)	0,22	41590
Hiroshima	0,15	-
Boston Massachusetts	0,1	187747
Porto Alegre	0,08	-
Stockholm	0,08	36000
Istanbul	0,06	3097464

4.1.4 Top 10 in high need for adaptation in the sample

Resulting from the previous description, we can see that almost all the most exposed cities are home to the busiest ports and are highly dependent on their port. Two of them are also between the most populated port cities studied in this research. Overall, there are a lot of mutual entries between the four groups, with Los Angeles being in all four top 10 sets, while Long Beach and Vancouver in three of the four and six other cities in two groups. The mutual port cities within the four groups are highlighted in figure 13. The importance of the adoption of CC adaptation measures in these port cities is obvious through this finding, especially for the most exposed ones.

Figure 13: The mutual port cities in the top 10 sample cities for different attributes

Busiest ports	Most populated municipalities	Most exposed port cities	Port cities with the highest RCI
Los Angeles California	Tokyo	New Orleans Louisiana	Durban
Long Beach California	Istanbul	Kobe	Seattle Washington
Tokyo	Lima	Osaka	Tacoma Washington
Istanbul	Rio de Janeiro	Tokyo	Miami Florida
Vancouver	Barcelona	Nagoya	Vancouver
Keelung	Dar es Salaam	Vancouver	Los Angeles California
Nagoya	New Taipei	Hiroshima	Long Beach California
Kobe	Los Angeles California	Long Beach California	Montreal
Melbourne	Cape Town	Los Angeles California	Houston Texas
Durban	Yokohama	Oakland California	New Orleans Louisiana

4.2 Port and city adaptation actions

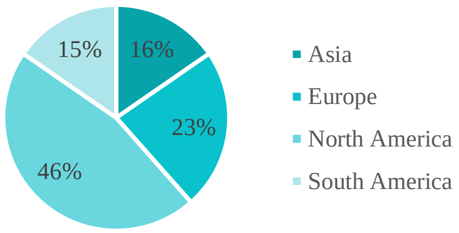
4.2.1 Survey responses from Port Authorities

The information on the adaptation actions of the ports is retrieved only through the responses to the questionnaire that was addressed to the 37 PAs. For this reason, a brief description of this group of respondents is provided in table 16. 14 of the 37 ports replied. One of the replies was negative, indicating that the port is not going to participate in the survey (Port of Melbourne). Japanese ports showed interest to participate, although the language and bureaucratic issues proved to be an important barrier. Finally only one of the six Japanese ports responded to the questions (Port of Osaka). Totally, 13 responses from people within the PAs can be utilized to map and analyze the adaptation response of ports towards CC.

Table 16: Port authorities that responded to the survey

City	Country	Continent	Port	Port Authority	Top 100 container ports ranking
Baltimore	USA	North America	Port of Baltimore	Maryland Department of Transportation - Port Administration	-
Boston	USA	North America	Massport	Massachusetts Port Authority	-
Cochin	India	Asia	Port of Cochin / Port of Kochi	Cochin Port Trust	-
Copenhagen	Denmark	Europe	CMP – Copenhagen Malmo Port	Copenhagen Malmo Port AB	-
Lima	Peru	South America	Port of Callao / Puerto de Callao	Empresa Nacional de Puertos S.A.	76
Lisbon	Portugal	Europe	Port of Lisbon / Port of Lisboa	Administracao Porto de Lisboa	-
Long Beach	USA	North America	Port of Long Beach	Long Beach Board of Harbor Commissioners	22
Los Angeles	USA	North America	Port of Los Angeles	Los Angeles Harbor Department	16
Malmo	Sweden	Europe	Copenhagen Malmo Port	Copenhagen Malmo Port AB	-
Montreal	Canada	North America	Port of Montreal	Montreal Port Authority	92
Osaka	Japan	Asia	Port of Osaka	Port & Harbor Bureau, City of Osaka	57
Porto Alegre	Brazil	South America	Porto de Porto Alegre	Administracao do Porto de Porto Alegre	-
Seattle	USA	North America	Port of Seattle	Port of Seattle Commission	73

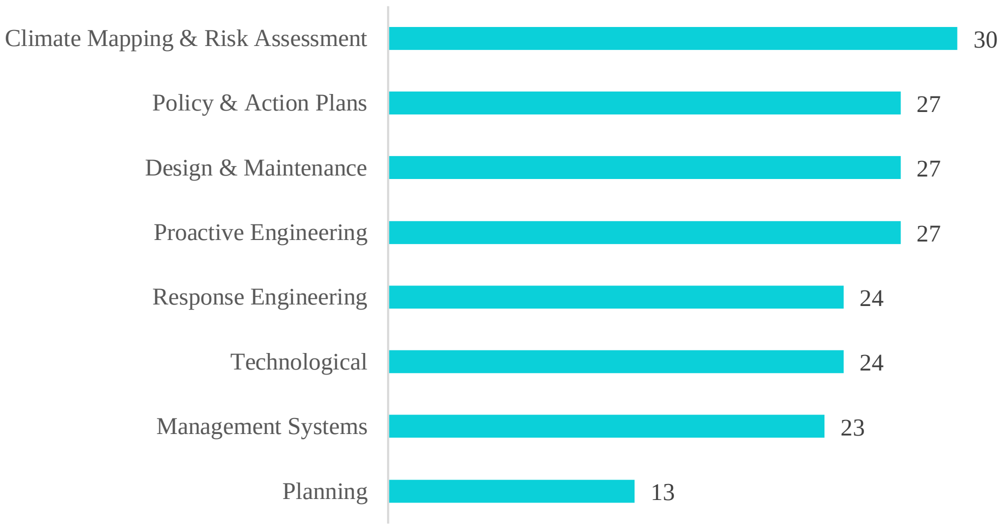
Chart 4: Percentage of ports that responded to the survey per continent



4.2.2 Port adaptation actions

The eight categories of port adaptation actions identified were retrieved through the literature, as has been mentioned. Each category is represented by three to five questions in the questionnaire, while most categories are equal with four questions each. After the responses received from the 13 PAs that participated in the survey, climate mapping and risk assessment proved to be the most popular actions category with 30 positive responses, followed by policy and action plans, design and maintenance and proactive engineering actions which receiver equal positive responses (27 each). Overall, most of the categories received between 23 and 30 positive responses, indicating a somehow balanced adaptation response.

Chart 5: Positive responses per action category from the 15 ports in the survey



Regarding the first action category, climate mapping and risk assessment, it is a strong indication of the realization of CC risk by ports. Moreover, it is a positive outcome that facilities data collection for further research on the subject and benefits the local communities but also knowledge on the global level.

Regarding one of the second most popular categories (policy and action plans) the survey result is opposite to the indication of Ng (2013) regarding the Australian ports, where Ng et al. observe a lack of plans. In the questionnaire survey, many of the ports reported even more plans, but under development. These answers could not be reported as definite positive responses, a change that would rank this category of actions as first among the rest.

However, the findings of the survey are in accordance to the indications of Ng et al. (2013) regarding design and maintenance, engineering and technological actions. The author explains that ports seem to be focused of implementation of actions that are related mostly to the everyday operations of the port, and not on "softer" actions. The questionnaire survey received a high number of positive answers in there categories, but slightly less for management systems and much less positive responses in the planning category, which ranks last with only 13 positive responses.

However, although the results on planning confirm the findings of previous study of Ng et al. (2013) on Australian ports, a more detailed examination of the data reveals that although only 35% of the total responses on planning were positive, the answers and comments convey an optimistic perception. Specifically, half of the ports indicated that the port is considering relocation of part of the facilities due to CC impacts, regardless of the complex nature of this issue, and that there is land use control regarding flood prone areas. Therefore, an explanation for the low amount of positive responses on planning may be the jurisdictional issues that it involves, that exceed the responsibilities of the PA in terms of permissions and financing. However, the positive answers regarding relocation within the sample are not concentrated at the northern hemisphere, as the pattern suggested by Nursey-Bray et al. (2013) but are spread globally.

On the contrary, only one of the 13 ports (Montreal) indicated plans to diversify the commodities handled by the port according to resilience factors. Specifically, regarding this question, the respondent from the Port of Seattle mentioned that an increase in the handling of grain products cargo is observed, due to the changing trends of food production in the USA, where as a consequence of CC and food technology, grains can now be grown closer to the port.

4.2.3 City adaptation actions

According to the cCCR, the adaptation actions are classified in seven categories, which reflect the various categorizations identified in the literature. Therefore, the classification of cCCR is preserved for this analysis, with the addition of the category "action plan / report" in order to describe documents that did not correspond to any of the categories other. The actions that had not been assigned to any sector in the cCCR, are assigned to the relevant categories. However, the previous classification of the actions by the municipalities that created the registry entries is not modified, as it required detailed review of the specific actions documents - which were not always available, and are published in different languages, Therefore, the perception of the LG officials who submitted the actions in the registry, or the classification of the actions by the municipalities, is the driver of the results of the research. The detailed actions per city are available in Annex 3. The total ranking of the types of adaptation actions identified for the 40 cities, can be seen in chart 6.

Chart 6: Number of actions per type, identified within the 40 municipalities

From chart 6, we can see that terrestrial ecosystems is the most common type of city adaptation action. However, 14 of the 40 recorded terrestrial ecosystems actions are indicated by Durban (eThekwini Municipality) which is the municipality with by far the most adaptation actions in the sample. The actions of Durban are 28, Buenos Aires is second with 12, and the rest cities have 10 or less adaptation actions. Regarding terrestrial ecosystems actions, although they prove to be very popular, the UNFCCC (2007) identifies an extended gap in literature regarding detailed information about their nature and specifications, compared to other actions categories.

From this ranking, even when it regards adaptation actions, we can identify the focus of the LGs on mitigation, as well as the prevalence of action plans and reports. Within the terrestrial ecosystems actions the majority regards green roofs, urban greening, reforestation and conservation of green spaces or parks. Some of them are still action plans but in relation to specific green resources, like the action "develop and implement a comprehensive urban forest management plan" of the City of Vancouver. Although these actions have co-benefits regarding CCA and CCM, the tendency of municipalities to prioritize mitigation is evident. Only a few of the 39 terrestrial ecosystems actions, like the "severe rain adaptations: long-runnel improvements at Arroyo Maldonado, rainwater runoff systems and lakes as flood buffers" of the Autonomous City of Buenos Aires, are principally adaptive.

Regarding the water resources actions, which is the third most popular category, the majority of the actions is indeed is related to adaptation to heavier precipitation, the ability to manage storm water and the improvement of drainage infrastructure. A smaller percentage is related to drought, water conservation and recycling. The next category that is strongly related to the risk of flooding is coastal zones / marine ecosystems, in which only 12 actions were identified for the 40 cities. However, they cover the whole range of mapping / assessment / planning / infrastructure construction and indicate a higher consistency regarding the risks identified and the responses described than most of the other categories.

It is worth noticing that some of the countries with very high exposure, like New Orleans who has also faced a flooding disaster in the recent past, have indicated no adaptation actions. However, although from other sources it is known that adaptation actions are planned, they were not confirmed by the City of New Orleans. Therefore the information from the official source of cCCR is used for this analysis.

Table 17: Coastal zones / marine ecosystems adaptation actions in the cCCR, for the selected cities

City	Coastal zones / marine ecosystems adaptation actions
Buenos Aires	Riachuelo River Bank
Cape Town	Coastal Edge and Coastal Protection Zone
Cape Town	Sea level Rise Risk Assessment
Dar es Salaam	Dar es Salaam Adaptive Structures Construction
Dar es Salaam	Kinondoni Integrated Coastal Area Management Project (KICAMP
Durban	Sea level rise assessment
Los Angeles California	Climate Adaptation Plan – Adapt LA: Sea Level Rise Vulnerability Assessment
Oakland California	Study Potential Local Climate Impacts
Seattle Washington	Inundation Mapping
Stockholm	Sea levels in Stockholm
Vancouver	Support and expand extreme heat planning
Vancouver	Clouds of Change Task Force

Health related actions concern mostly preparedness about diseases such as Dengue fever, and also actions regarding global warming like monitoring the climate temperature, white roofs, mobile refrigeration units. Infrastructure actions include a variety of sectors but regarding infrastructural requirements. Water drainage and greening, especially green roofs, are the most common within the actions. Regarding the early warning systems / disaster management actions, they are based on the preparedness for hurricanes and typhoons ("Taipei city typhoon and flooding crisis emergency plan") but also monitoring of meteorological conditions and decision making ("development of a GIS-based decision support system for urban air quality management", Istanbul Metropolitan Municipality). The least popular type of adaptation actions, food security, regards mainly urban agriculture. One very specialized food security adaptation action was identified, the "Luganda school water harvesting and micro agricultural water management technology", in Durban, South Africa.

In total, we observe that the risk of flooding from SLR and storm surges, is conceded and apparent in most categories of adaptation actions. Also in terms of number of actions, the water resources and coastal zones / marine ecosystems categories combined present a high number of actions related to this risk, and is the most popular category if we critically assess the content of the terrestrial ecosystems actions. However, "early warning systems / disaster management" is a category that requires more attention due to the lack of actions in the majority of the cities as the identified nine actions have been adopted in six cities, three of them in New Taipei City.

4.3 Port city exposure in relation to the adaptation actions of the port and the city

The next part of the analysis aims to explore how the identified adaptation actions relate to the exposure risk of the port cities to CC, as it was identified by Hanson et al. (2010). Because of the differences between the cities as they are taken into consideration from Hanson et al. (as urban agglomerations) and the entries that are presented in cCCR (as specific municipalities), adjustments to the exposure values have been made for the consistency of the values that are examined. As an example, in the case for Melbourne, the City of Melbourne (which is the cCCR entry) takes up only 0,5% of the Metropolitan Area of Melbourne, which was used to calculate the exposure by Hanson et al. (2010). The values were adjusted proportionally, according to the area of the municipality. Therefore, the spatial factor, and not population, was taken into account as a more reliable measure.

As it is shown in figure 14, the actions of the port slightly decline as the port city exposure increases ($r_{(exp,port)}$= -0,10). However, none of the ports indicates zero actions. Regarding the actions of the cities they also decline as exposure increases ($r_{(exp,city)}$= -0,21), eventually reaching zero. Five of the cities in the sample have indicated the adoption of zero adaptation actions.

The analysis of the actions per type in relation to exposure provides us with more detailed information. As far as the city is concerned, all types of actions are declining as the exposure increases. However, the technological and especially the response engineering actions of the ports have a positive relationship with the port city's exposure, and increase as the exposure increases ($r_{(exp,tech)}$=0,11, $r_{(exp,reng)}$=0,55).

This conclusion is reasonable, in terms of the expected prioritization of actions. We could assume that indeed, response engineering would be the first priority regarding the response to exposure risk when port operations are taken into account. Similarly, technological actions (like automation and storages suitable for wide temperature range) would be expected to be a priority regarding the protection of employees and handled cargo in case of emergency.

Regarding the tendencies identified between the exposure and the city actions, they proved to be not statistically significant according to the Pearson correlation's P- value (p_{port}=0,77, p_{city}=0,21).

Table 18: Port attributes in relation to the types of port adaptation actions

		Exposure	RCI	TEUs
Total port actions	Pearson Correlation	-0,096	0,048	-0,256
	Sig. (2-tailed)	0,767	0,876	0,422
Technological	Pearson Correlation	0,113	-0,058	0,076
	Sig. (2-tailed)	0,728	0,850	0,814
Proactive engineering	Pearson Correlation	-0,562	-0,025	-0,460
	Sig. (2-tailed)	0,057	0,935	0,132
Response engineering	Pearson Correlation	0,551	-0,036	0,429
	Sig. (2-tailed)	0,063	0,907	0,164
Design & maintenance	Pearson Correlation	0,039	0,122	-0,371
	Sig. (2-tailed)	0,903	0,692	0,236
Planning	Pearson Correlation	-0,113	0,317	-0,029
	Sig. (2-tailed)	0,727	0,292	0,928
Climate mapping & risk assessment	Pearson Correlation	-0,305	0,214	-0,224
	Sig. (2-tailed)	0,335	0,482	0,485
Management	Pearson Correlation	-0,074	-0,014	-0,112
	Sig. (2-tailed)	0,820	0,965	0,730
Policy and action plans	Pearson Correlation	-0,176	-0,126	-0,402
	Sig. (2-tailed)	0,584	0,681	0,195

Table 19: City attributes in relation to the types of city adaptation actions

		Exposure	RCI	Population density	City GDP per capita
Total city actions	Pearson Correlation	-0,212	0,527	-0,084	-0,150
	Sig. (2-tailed)	0,207	0,000	0,606	0,355
Action plans and reports	Pearson Correlation	-0,126	0,540	-0,248	-0,219
	Sig. (2-tailed)	0,792	0,000	0,123	0,175
Coastal zones / marine ecosystems	Pearson Correlation	-0,137	0,230	-0,136	-0,147
	Sig. (2-tailed)	0,419	0,153	0,404	0,364
Early warning systems / disaster management	Pearson Correlation	-0,040	-0,107	0,467	0,011
	Sig. (2-tailed)	0,815	0,509	0,002	0,949
Food security	Pearson Correlation	-0,097	0,228	-0,187	0,016
	Sig. (2-tailed)	0,569	0,157	0,247	0,921
Health	Pearson Correlation	-0,168	0,029	0,003	0,169
	Sig. (2-tailed)	0,320	0,857	0,984	0,296
Infrastructure	Pearson Correlation	-0,087	0,363	0,038	0,000
	Sig. (2-tailed)	0,607	0,021	0,815	0,999
Terrestrial ecosystems	Pearson Correlation	-0,135	0,468	-0,058	-0,186
	Sig. (2-tailed)	0,426	0,002	0,724	0,251
Water resources	Pearson Correlation	-0,209	0,203	-0,011	-0,026
	Sig. (2-tailed)	0,214	0,210	0,947	0,874

4.4 Port-city relationship regarding Climate Change

4.4.1 RCI in relation to the actions of the port and the city

The port-city relationship is expressed through the RCI values of the cities as they were calculated for Ducruet & Lee (2006) for the container throughput and population of the cities in 2005 – as this is the most recent calculation. Regarding the relation between the RCI and the number of adaptation actions, it does not appear to strongly relate to the actions of the port, but shows a positive relation to the adoption of actions by the cities (according to Spearman correlation, $r_{(rci,port)}$=0,53 and $r_{(rci,city)}$=0,05).

What can be inferred by figure 17 is that the higher the dependence of the city to the port, the more adaptation actions are taken by the LG. However, the separate analysis of each type of action reveals that the higher dependence by the port (higher RCI value) affects negatively the following types of actions: early warning systems / disaster management, and health. This inevitably generates the assumption that cities that are more dependent on their port, are less community-oriented, not adopting actions that have a direct impact on lives and health saved. On the contrary, the dependence on the port seems to generate the interest for actions related to coastal zones / marine ecosystems, infrastructure and food security as would be expected.

The data regarding the total adaptation actions adopted by the examined cities proved to have a statistical significance relation to the RCI values, with P-value < 0,05 ($P_{rci,city}$ = 0,15).

As far as the port's types of actions are concerned, RCI appears to affect mostly the adoption of action plans and policy actions (in a negative way), indicating that better port performance (or in other words less dependence of the port from the city) leads to less action plans and policies. However, this assumption regarding this action type will be tested and validated also in relation to the port TEU performance, further on in this chapter. On the other hand, ports in ports cities with higher RCI values tend to adopt more actions related to climate mapping and risk assessment, indicating the realization of responsibility regarding CC issues. This is a positive finding, as the ports seem to act also in favor of the community, when they precede the city in the port-city system.

4.4.2 RCI in relation to port performance and city population density

As the RCI is the ratio between container throughput and population, it is a figure that should be increasing according to higher port performance. Indeed we can confirm this in chart 8, where we observe that for the studied port cities, the overall tendency of the relation between the RCI and the TEUs is inclining. As through the literature it is recognized that the ideal relationship between the port and the city would be for RCI values 0,75-1,25, from this graph it can be concluded that the two cities with the highest TEU performance also prove a balance between their land and marine functions. These two values in the graph represent the port complex of Los Angeles and Long Beach.

Nevertheless, the opposite relation exists between the RCI and population density as would be expected. The vast amount of values is concentrated on the lower RCI measurements, for which a variety of densities is observed, also reaching very high population density numbers.

The trend line is decreasing as the RCI values increase and are indicating the dependence of the city to the port. Therefore, the denser a city is, the more it depends on its own structure than to the port. The two extremes in chart 9 are Durban (RCI=2,25, density=1.498,6) and Taipei / New Taipei (RCI=0,43, density=15.200). A city described by a balanced relation between RCI and density is Cochin in India (RCI=1,04, density=6340,4).

These observations, supported by the following charts, validate basic assumptions regarding main indicators of the research, and confirm their relevance in the associations that are made in the analysis.

Chart 7: Ports' performance (in TEUs) in relation to the RCI of the selected port cities

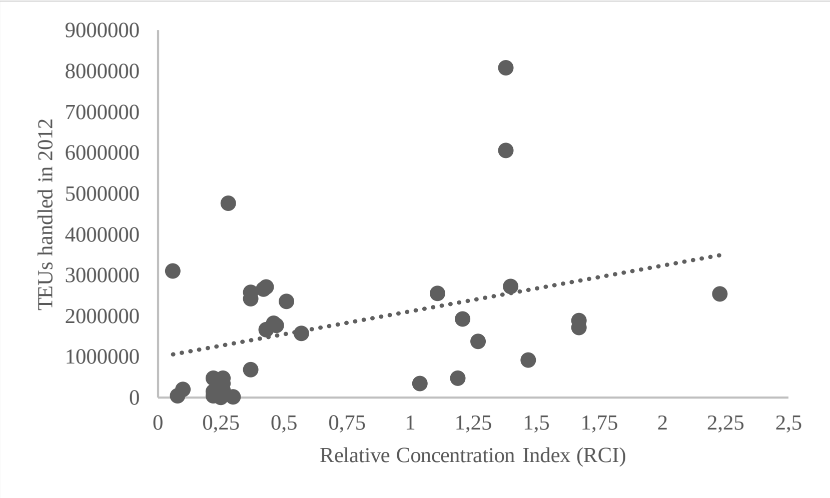
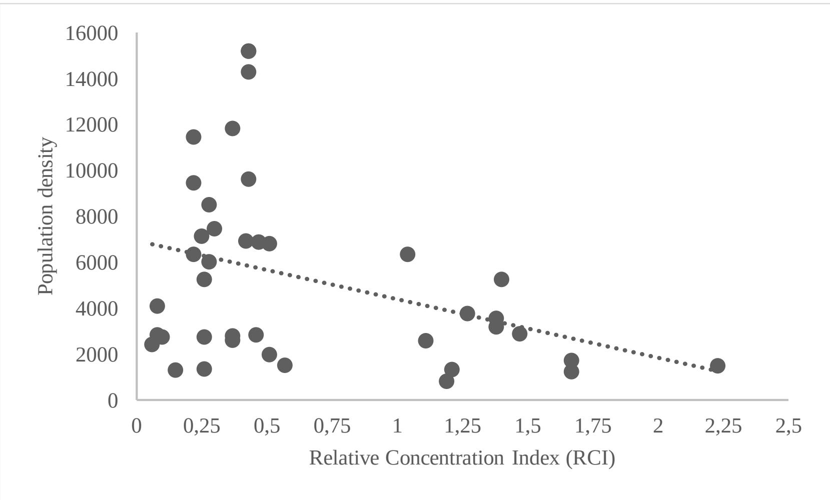


Chart 8: Population density in relation to the RCI of the selected port cities



4.4.3 Port Authority – Local Government collaboration on Climate Change

Regarding the relationship between the PA and the LG, two questions were incorporated in the questionnaire. Firstly, the collaboration of the port with the LG to plan and design connections to logistics hubs resilient to impacts of CC was explored. Secondly, whether the PA cooperates with the LG on CC adaptation. Regarding the first question, 30% of the responses were positive. However, the positive responses for the second question accounted for 69% of the cities that replied to the survey.

As far as the specific questions regarding the port-city relationship that were addressed to the ports are concerned, the responses indicate a vague connection. Although the majority of PAs claim to cooperate with the LG on CCA, only 30% collaborate on the connection of the port and the city's transport infrastructure to resilient logistic hubs. However, this is the most prominent relationship between the port and the city, also identified by Ng et al. (2013). The port as a major transportation node (possibly the most important infrastructure hub of the city and also one of its most valuable assets) would be the main actor for the LG of the port city to collaborate with, regarding CCA. Moreover, it was observed that the positive responses regarding this collaboration are less in cities with a higher RCI value.

Chart 9: Survey responses regarding the collaboration of PA and LG on planning resilient logistics hubs

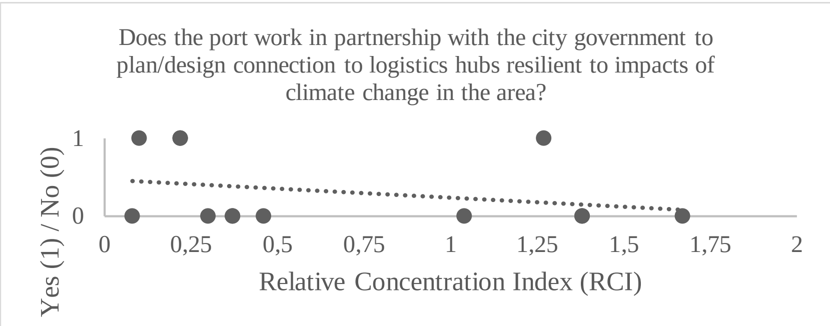
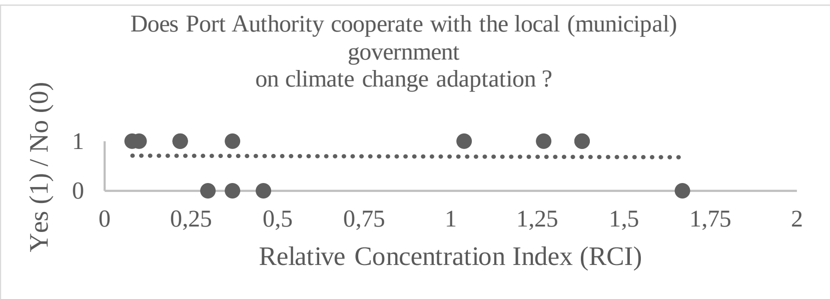
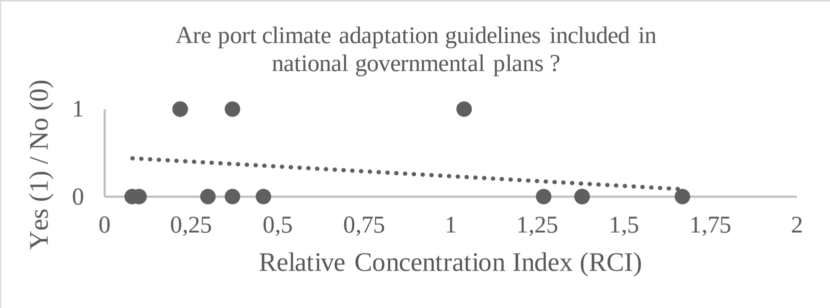


Chart 10: Survey responses regarding the collaboration of PA and LG on CCA



Regarding the question on the inclusion of port adaptation actions in national documents, only 34% of the answers were positive, from USA, Denmark, India, and Sweden.

Chart 11: Survey responses regarding the consideration of port adaptation in national plans



4.5 Port and city attributes, in relation to their adaptation actions

4.5.1 Port adaptation actions in relation to port performance

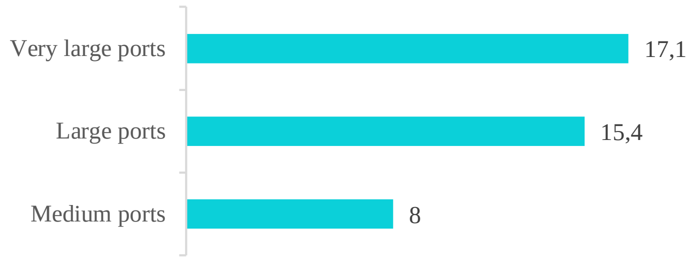
The relation between the numbers of adaptation actions of the ports, in comparison to the ports performance (TEUs handled) tends to be negative, for the ports in this research. Therefore, as it was already assumed from the identified relation between RCI and port actions, the better the port performance is, the less attention is paid to CCA by the port. The most negative tendencies concern action plans and policies, confirming the previous finding from the correlation between action plan and policy actions to the RCI, but also proactive engineering actions – as opposed to response engineering which is increasing as the performance improves.

However, the separate examination of the categories of actions indicates that only the technological and response engineering actions increase, with the improvement of port performance. Response engineering actions include upgraded drainage systems, raised roadways and rail tracks, raised port elevations and water retention basins in order to respond to flooding events. All of these characteristics are closely related to the trustworthiness of the port for the operators, as does also the adoption of technological actions which are related to the durability of the technological equipment of the port, and the integration of automation in port operations. Another technological action that can indicate the steadiness of the port and potentially play a role to the improvement of its performance is onsite renewable energy production.

4.5.2 Port adaptation actions in relation to the port size

According to the responses of the ports to the questionnaire, port size is evidently related to the adoption of adaptation actions. Ports of medium size take on average less than half adaptation actions, compared to very large ports. Large ports take on average 15,4 actions, slightly less than very large ports with 17,1 total actions per port.

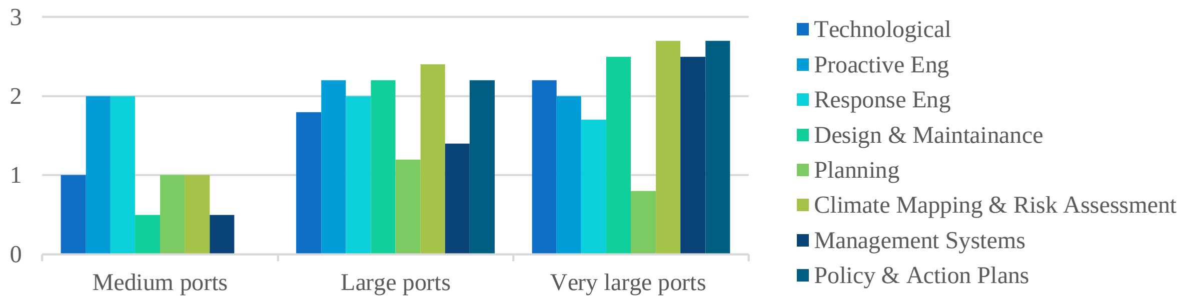
Chart 12: Average of total port adaptation actions per port, according to port size.



Regarding the type of actions according to the port size, we notice that regarding engineering actions the size does not play a major role as all three types of ports showcase values around two actions per port. Planning is a similar category, as medium to very large ports indicated the adoption on one planning action on average. However, big differences occur regarding the existence of policy & action plans, as medium ports demonstrate zero actions, while very large ports almost three actions on average, which is the highest value identified.

This is also verified in the study of Ng, as in Australia the biggest ports indicated more CC responses, and combined adaptation and mitigation actions. According to the same author, bigger ports are more concerned about the impacts of extreme climate events and CC on the operations of the port, while smaller ports about the performance of other sectors on which they depend on, such as the agricultural sector, the condition of neighboring ports or the community of the port city. However, from the data analysis, regarding this port sample, smaller ports (which are limited to medium size) ranked less than bigger ports in all categories except for proactive and response engineering.

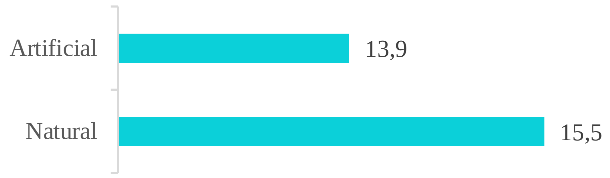
Chart 13: Average amount of actions adopted per type, according to port size



4.5.3 Port adaptation actions in relation to the port creation process

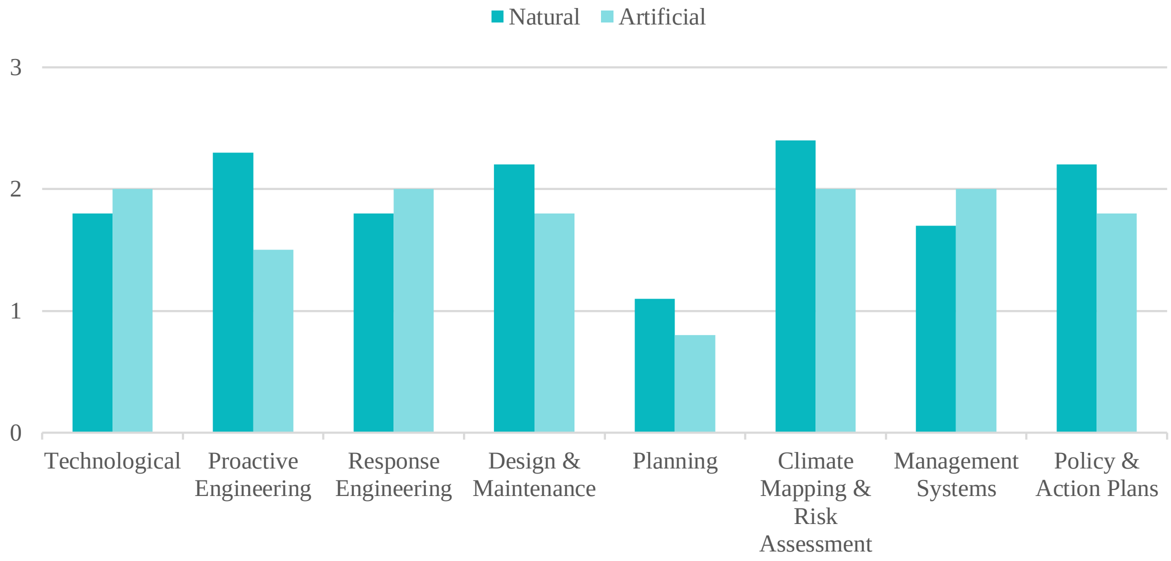
Within the 13 ports that responded, 9 are natural harbors (69%) and 4 artificially constructed ports (31%). Through literature review, artificial ports have in many cases faced environmental and climatic difficulties related to concentration of sediment, required dredging, changes in sea water flow patterns and also changes in the ecosystem (Maia et al. 1998). These difficulties lead to increased construction and maintenance costs, as well as to higher exposure to meteorological conditions. Opposed to the hypothesis that artificial ports would adopt more actions due to their increased risk, natural ports seem to be more responsive to CC.

Chart 14: Average of total port adaptation actions per port, according to the ports' creation process



Regarding the types of actions, there are no important differences between the recorded responses, as both natural and artificial ports display similar values. The biggest difference regards technological actions. Especially regarding climate mapping and risk assessment, where it would be expected that artificial ports would take more actions, this is not confirmed. However, we observe that indeed artificial ports take more actions regarding response engineering (such as elevated facilities and upgraded drainage systems) as they are more prone to face flooding even with less extreme weather conditions.

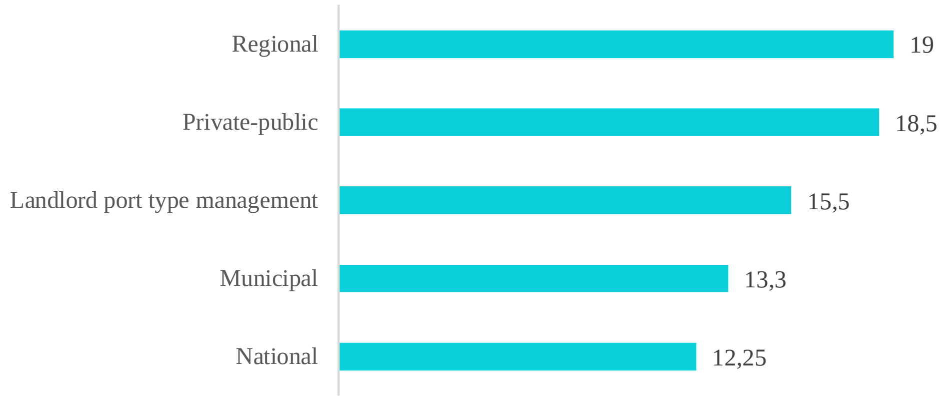
Chart 15: Average of actions adopted per type, according to the ports' creation process



4.5.4 Port adaptation actions in relation to the types of Port Authority

As far as the PA typology is concerned, we observe that regional and public-private ports take the most adaptation actions. Following these categories is the landlord port type management PA, followed by the municipal and last, the national ports.

Chart 16: Average number of total actions per port, according to the type of PAs



However, from the following chart (chart 18) we observe that within the Regional ports there in an unequal distribution of the actions between the different typologies, while the landlord port type management and national ports show the most balanced approaches.

Chart 17: Extend of adaptation response of each port authority type

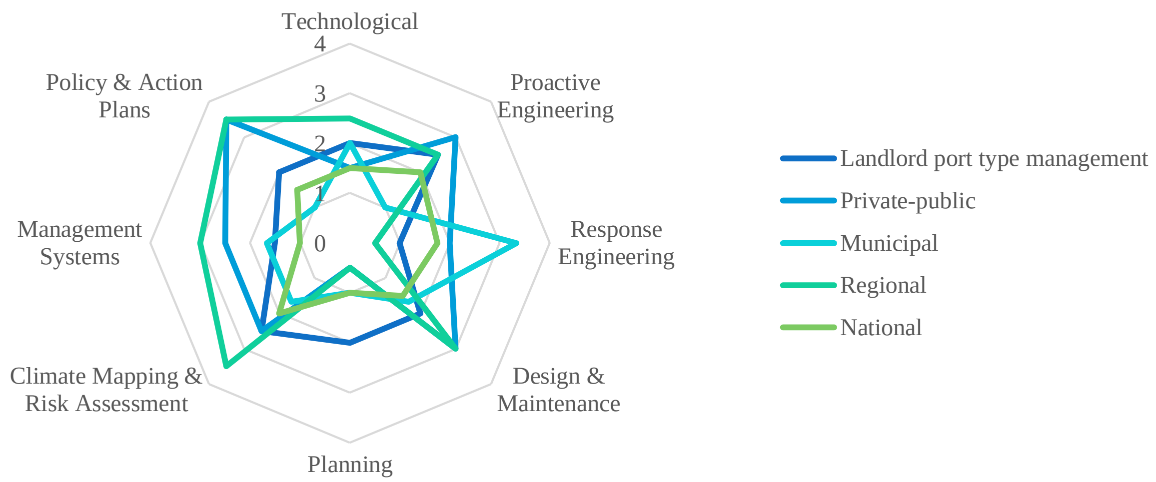
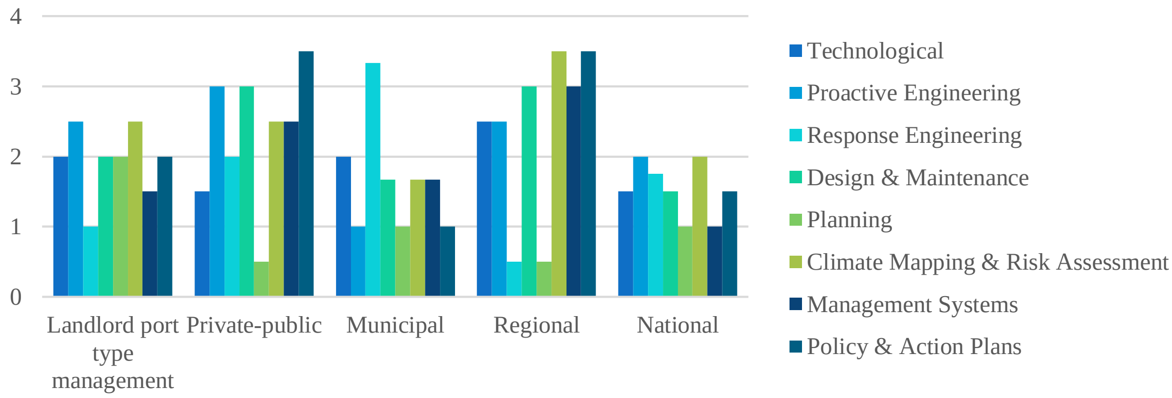


Chart 18: Average number of actions per type, adopted by the different types of PAs



4.5.5 City adaptation actions in relation to city population density

Opposite to what would be expected, the relation between the total city adaptation actions and the population density appears to be negative. As the population density increases, adaptation actions are reduced, finally approaching zero.

However, in the more detailed analysis regarding each action typology separately, we see that early warning systems / disaster management as well as health actions are increasing in denser cities, indicating social awareness. Although these action categories were not affected positively by exposure, population density proves an important factor for their adoption, especially for early warning systems which also indicate a significant correlation to density ($r_{(dens,ewsdm)}$=0,467, $p_{(dens,ewsdm)}$=0,002). However, food security actions continuously decrease, although they indicate also a social concern. Infrastructure actions is the last typology that increases by density, as well.

4.5.6 City adaptation actions in relation to city GDP per capita

The observed relationship between the city GDP per capita and the overall adoption of adaptation actions by the city proves to be slightly negative ($r_{(gpd,city)}$=-0,150, $p_{(gdp,city)}$=0,335). However, some action types indicate a somehow positive correlation: early warning systems / disaster management, food security, but mostly health actions.

Although the significance of the findings related to city GDP per capita in not high, through observation of the tendencies we can comment that as the GDP per capita increases, the actions adopted tend to be more of humanistic nature, and also related to quality of infrastructure, connected to quality of life. However, attention is drawn away from precaution for disaster avoiding measures, and also from actions with mitigation co-benefits. In addition, the higher the city GDP per capita is, the less action plans and reports the cities publish, indicating a lack of interest to plan according to CC and also to raise societal awareness, which is a major factor for the city's resilience.

4.5.7 City adaptation actions in relation to the city geography

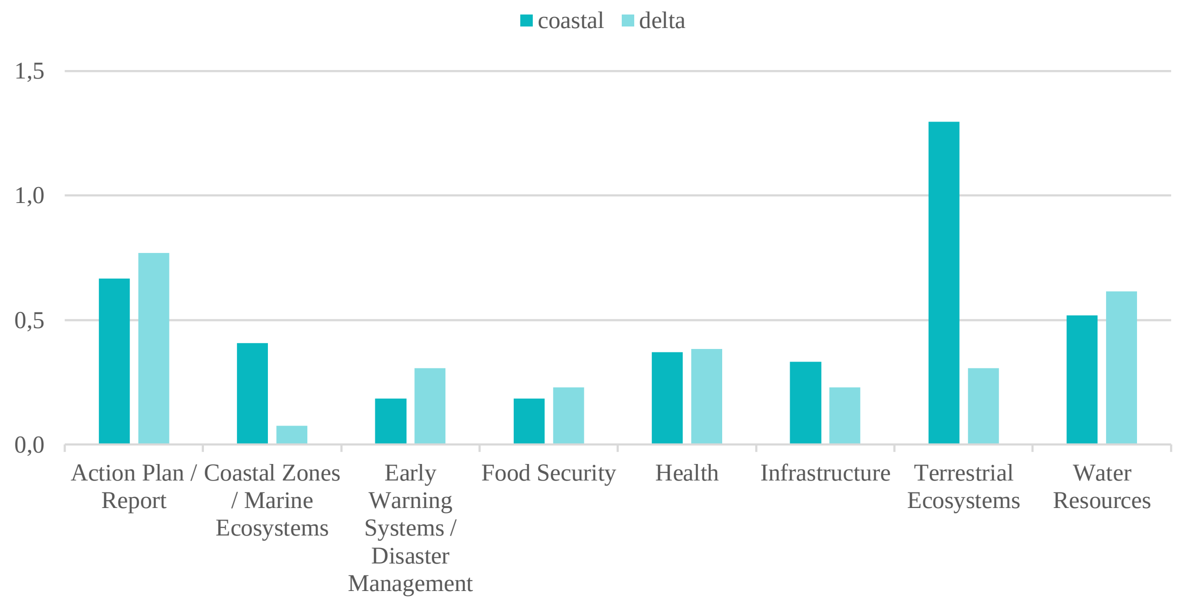
As far as the distinction of port cities between delta and coastal cities is concerned, we see that although delta cities seem to adapt less actions than non-delta ones (a finding that is opposite to what would be expected according to the high exposure risk of delta cities), the rest of the findings confirm the literature and previous research indications.

Chart 19: Average adaptation actions adopted by delta and coastal cities

Specifically, in chart 20 we can see that the biggest differences between the two port city types occur for coastal zones and marine ecosystems actions as well as for terrestrial ecosystems, where coastal cities are more active.

However, we observe that delta cities have (slightly) more actions regarding water resources, early warning systems, food security and health. They display a more human – based response, with focus on water resources. The really low amount of coastal zones / marine ecosystems actions is the indication that can be considered unexpected and certainly inadequate, although stressing out that indeed there is a difference between the responses of delta and non-delta cities on critical types of actions.

Chart 20: Average adaptation actions per type adopted by delta and coastal cities



Chapter 5: Conclusions

5.1 Adaptation response of port cities

5.1.1 Introduction

From the conducted data analysis, we can identify a variety of trends and responses regarding the adaptation actions of port cities around the world. This is also the result of the context specific nature of adaptation, and the wide geographical and socioeconomic range of the port cities examined. However, a difference between the sensitivity of the port and the city to their exposure and other characteristics can be observed. The following conclusions are structured according to the specific research objectives stated in the previous chapters.

5.1.2 Relation between exposure and adaptation actions of port and city

The exposure of the port city to flooding and subsidence indicated negative correlation to both the actions of the port and the city. However, there are the exceptions of the technological and response engineering actions of ports which increase rapidly as the exposure increases, especially the latter. Response engineering actions such as the existence of advanced drainage systems that cope with projected rain events, raised roadways, rail tracks and port elevations that respond to flooding and water retention basins, indicate high correlation with exposure ($r_{(exp,reng)}$=0,551 $p_{(exp,reng)}$=0,063). However, the other exposure correlation that proves interesting is with the proactive engineering actions. This relation shows almost the exact opposite tendency than response engineering actions ($r_{(exp,peng)}$=-0,562 $p_{(exp,peng)}$=0,057) indicating that engineering actions seem to be the most important type of action for ports. However, "protection" as it is described by UNFCCC (2007) is paid much less attention than "retreat" through disaster preparedness.

Regarding the city, the actions typology that shows the least (negative) correlation with exposure are water resources actions ($r_{(exp,water)}$=-0,209 $p_{(exp,peng)}$=0,214), although this result is not of significance.

5.1.3 Port-city relation and the collaboration between PA-LG on climate change

Regarding the RCI, namely the dependence of the city on its port, it provides the strongest relation identified in the research, also highly significant. This correlation regards the actions of the city, and not the port. Regarding the port, the relation of the actions with the RCI is weak and not of clear direction. However, regarding the city, the correlation of the city total actions but also of specific typologies such as action plans and reports, infrastructure and terrestrial ecosystems are strong and significant as shown in table 19.

This observation can be interpreted in both a positive and a negative way. Starting from the negative side, we understand that the more the city depends on its port, the more adaptation actions it adopts. In other words, there is an underlying inability of the LG to realise the climate risk to which the city is exposed, unless there are eminent economic risks and consequences involved. Similarly, the relation of the city's actions to the exposure builds on the previous conclusion. The more exposed the city, adaptation actions do not increase as we would expect, but on the contrary they steeply decrease, eventually reaching zero.

On the other side, the optimistic conclusion that can be inferred from this observation is that the more dependent the city is on its port, the more its attention is focused on the quality of infrastructure, but also actions with mitigation co-benefits (such as terrestrial ecosystems actions) and plans for future sustainability and resilience. Therefore, the competitive development and global perspectives of the port (as the RCI involves containerized and not total cargo throughput) seem to have a positive effect in the overall adaptation response of the city (although not regarding human focused actions such as health, which is the least related sector among all the actions types). However, we can assume that the increase of adaptation awareness will gradually affect all sectors, and it is certainly a positive fact that the performance of the port, which is the main goal of ports worldwide, can trigger adaptation activity for port cities.

Nevertheless, although through this high interdependence we can easily observe the positive outcomes that the collaboration between port and city may entail, regarding CCA, the data analysis indicated that this collaboration is not happening at a confident level. Although there seems to be an understanding for this need, and some institutional or official relations may exist between the PAs and LGs, or even the national government, more detailed examination reveals that this indications are not substantial.

5.1.4 Relation between port attributes and port adaptation actions

The port attributes that were examined were port performance measured in TEUs (due to the global scope of the research and the climatic phenomena, and the relation of this unit to containerization), port size, the process of the port construction (natural/artificial) and the different types of PAs.

The conclusion that stems out from the analysis is that the port size and PA type are more related to the adoption of adaptation actions. Specifically, we see that large and especially very large ports adapt a much larger amount of actions on average. The same conclusion can be reached about regional and private-public ports. However, both these observations reveal also high inequalities among the types of actions. We recognise that although larger ports with regional reach and private-public ports may adopt more actions, they are focused on specific typologies which in both cases do not include planning - although it is of vital importance. Therefore, a more integrated approach can be suggested.

Resulting from the aforementioned, port size rather than TEU performance seems to play a more important role for adaptation actions. Larger ports, possibly also busier in terms of general cargo handled apart from containers, seem to consider CC impacts and implement more actions. As a result, we can assume that large ports are keener on protecting their assets, and also making an impact on the city. As examples from the studied sample, the three ports with the lowest handled TEUs (Boston, Copenhagen and Lisbon) but with prominent activities in the field of cruising, are ports of large and very large size, and two of them, Boston and Copenhagen, have adopted the highest number of actions among the ports in the sample (23 and 20 actions respectively) while Lisbon has also taken a considerable number of actions (12). Indeed, regarding the aforementioned ports, we can identify from various sources like their webpages and their action plans and policies that they are oriented towards the community, and prove social and environmental concerns.

These findings highlight that the busiest container ports do not coincide with the largest ones, as general cargo remains the most popular cargo type although the vast containerisation of sea trade. Therefore, we can conclude that the more globally oriented the port is, (i.e the more it has incorporated container handling in its operations), the less adaptation actions it adopts, as the attention is focused on port performance rather than less imminent effects – such as CC.

Regarding the port creation process, the unexpected conclusion that artificial ports take less adaptation actions on average was reached. This observation can be attributed to the closer relation of natural ports with the city, as also regarding their RCI values, the average RCI of the natural ports in the sample is 0,6 which is lower to the average RCI of artificial ports, that is 0,9. Accordingly, natural ports appear to be part of less port-dependent cities, oriented to the urban functions. On the contrary, port cities with artificial ports indicate a higher dependency on the port function – but at the same time, a more balanced port-city relationship according to the RCI interpretation.

Planning is still the lowest adopted action type in both artificial and natural ports, a fact that proves a general lack of planning regarding CC from the side of the port. Similar conclusions were also reached regarding the relation of port adaptation actions and exposure, leading to a verification of the overall conclusions direction.

5.1.5 Relation between city attributes and city adaptation actions

The city attributes that were examined through the data analysis are population density, city GDP per capita and the differences based on whether the city is a delta or a coastal port city.

We observe that the adaptation action types that tend to precede triggered by these characteristics are health, food security and early warning systems actions. However, this human based approach, which would be expected from cities, does not always lead to positive conclusions: although it increases with higher density, it also increases with higher city GDP per capita, which means that wealthier societies pay more attention to the wellbeing and the safety of the population. Although in the sample some of the wealthiest cities are also within the most exposed, cities in developing countries with low GDP per capita should also be paying attention to this types of actions.

However, regarding the cities, the general need to restructure their adaptation response and take more actions, of wider framework in consideration is identified. The only significant finding regarding the city attributes was the strong correlation between high density and early warning systems, which is indeed a positive indication, as a recognition and the beginning of action for CC resilience.

Regarding the distinction between delta and non-delta cities, the overall response is almost equal, with the exception of terrestrial ecosystems and coastal zones actions. In general, we observe that both types of cities adopt on average more water resources and action plan / report actions in comparison to the rest of the typologies.

5.2 Climate change adaptation equilibrium between port and city

5.2.1 The prevalence of the port as an opportunity for the city

Overall, regarding CCA, the equilibrium between the port and the city, as perceived from the analysis of the selected 40 cities, leans towards the side of the port. The city seems to be more sensitive to external factors such as geographical exposure and dependence on the port, mostly in ways that affect its adaptive capacity development in a negative way. On the other hand, the port appears as a more independent entity, which focuses on performance and the most vital adaptation actions which are win-win decisions regarding the operation of the port. The internal port attributes such as port size and the port authority type play a more important role to the adoption of adaptation actions by the PAs.

The conclusion that we can reach by taking these observations into consideration is that there is indeed a considerable interdependence between the two entities in the port-city system, although this is evident mainly from the perspective of the city. This relationship seems to be affecting the city in a non-positive way, noticeably influenced by the port's performance. As Merk & Dang (2013) also note, the prosperity of the port city seems to be highly related with port activity like value-added and availability of employment. However, as already mentioned this evident relation between port and city is the opportunity on which port cities can focus and elaborate on.

Regarding the realization of CC risk, as Ng (2013) also highlights in his research, ports and cities prove to be clearly aware of it. This phenomenon is obvious from the ranking of the actions typologies as well: for both the port and the city, action plans, policies, reports, climate mapping and risk assessment regarding CC are the most popular CCA typologies showing an overall involvement with CC. However, their adaptation responses remain fragmented.

From the ranking of the actions' categories, we have identified different tendencies regarding the focus of the port and the city. On one hand, the port seems to focus on short term actions such as engineering or design & maintenance, and leave planning as a last priority. On the other hand, the city is mostly oriented towards CCM, and certain characteristics such as density and GDP seem to increase its health or food security actions, with coastal zones/marine ecosystems and early warning systems among the less popular action categories - a result opposite to the anticipated priorities of port cities with high exposure to CC.

As Ng (2013, p. 186) emphasizes commenting on Australian ports, "effective adaptation strategies are not only about physical layouts and engineering projects but the need to fundamentally transform the current management and planning practices of ports". The sample examined indeed validates this statement regarding the ports but contends the opposite, regarding the cities: more concrete actions need to be taken, directly related to building adaptive capacity and response mechanisms to the imminent threats of climate hazards.

5.2.2 Evaluation of the factors examined

It has to be highlighted that the conclusions reached through this analysis, as has also been mentioned in the methodology chapter, are based on information which depends on several factors, challenging the ultimate subjectivity of the results. At first, the actions of the ports analysed result from the personal perceptions of the respondents within the environmental departments of the PAs. In addition, the entries and information in the cCCR are result of non-verified submission of information by the LGs, which in some cases obviously does not represent the current situation. Moreover, in some cases municipalities added information to the database during the research, but in stages that the new information could not be added in the research due to time limitations.

Apart from these factors, other variables which it was not possible to examine due to the time and cost requirements could be affecting the conclusions reached. For example, the consequences of adopting or planning specific types of actions in each context, due to land requirements, legislative issues, financial constraints and political implications was not possible to be examined. In addition, the existence of actions that are not enlisted, or are categorised under different typologies could not be explored, as it would require extensive research on each port city. Finally, factors such as the connectivity and infrastructural resilience of the port and the city, as well as the total cargo except from containers that the port city system handles and its effect on the city functions and urban population according to contextual conditions are factors that are closely related to the subject studied, but was not possible to be studied within this research.

5.3 Port-city synergy possibilities

5.3.1 Multi-level and multi-scale collaboration

Throughout the literature, the need for partnerships between different parties and stakeholders (UNCTAD 2011), the collaboration of the port with the local, regional and national governements (Nursey-Bray et al. 2013), but also the knowledge exchange in international level (Nursey-Bray et al. 2013, UNFCCC 2007) is underlined, in order to approach CCA in a holistic, significant manner.

Synergies are required and can be introduced through policies, planning, financing and investment mechanisms. As CC is a multidisciplinary and complex issue, it can only be addressed successfully with alliances that cut through various scales and levels of the human – environment interactions (Cash et al. 2006). Interactions between the spatial, temporal, jurisdictional, institutional and managerial scales could address the inconsistencies that are identified within the port-city system. At the same time, adjustments among the local to national and international governments and organizations, synchronization of actions, projects and strategies, and reforms of laws and regulations to enunciate the temporary port city establishment would enable the implementation of CCA and enhance its impact on both the local and global level.

However, at the same time, as Pesquera & Ruiz (1996, p. 15) mention, "the durability of city ports calls for a new commitment between ports and cities". Therefore, the special identity of port cities should be conserved and remain obvious, in order for their dynamics to be utilized and the port-city system to function competitively. The same authors, concerned on the relation between the port and the city recommend "the reformulation of the existing parameters of their relationship and understanding, the alteration of predetermining equilibria and the construction of a new framework for their relationship" (Pesquera & Ruiz 1996, p. 15)

5.3.2 Port-city collaboration

Resulting from the literature and analysis, the multi-level and multi-scale collaborations in the port-city system could take advantage of the close relation between the port performance and the city adaptation response, and focus on capitalising on this mutual interest. Starting from a mutual collaboration on planning, both the interests of the port and the city could be addressed successfully. Planning for improved and well-connected infrastructure can advance the port as a supply chain hub, as well as reduce the negative spilovers of traffic within the urban environment. This is already an action with mitigation co-benefits, that would affect also the quality of life and the need for health adaptation actions.

Moreover, climate mapping and risk assessment as a joint venture from both the port and the city could provide a clearer and wider picture regarding the specific needs for adaptation. Being more confident on the possible circumstances and consequences could reduce risks and lead to better collaboration on early warning systems and design of disaster management mechanisms.

In addition, collaboration on coastal zones and marine ecosystems as well as on terrestrial ecosystems actions through ICZM, could unveil the potential of the port city coasts and resources and lead to an integration of city functions that also highlights the city's competitive, port identity. As has been identified in the literature, this competitive urban environment would benefit both entities and lead to economic and social development as well.

5.4 Future research

Regarding future research on the subject of port cities and CC, more detailed analysis with regard to the specific geographical aspects and risks of port cities, and the actions that should be introduced or strengthened in each context would be beneficial. Moreover, regarding the global scale, a wider sample and extended research is necessary in order to identify the responses of a larger amount of ports and cities, and reach more robust conclusions. This study, although the sample can be considered representative and confirms literature review findings, was conducted during the finite research period, limiting the information that could be retrieved within this timeframe.

Moreover, detailed revision of the action plans and policy documents on port, municipal and national level would be a fruitful investigation. Similar research has been conducted by OECD regarding the effectiveness of port city policies (Merk & Dang 2013), however not specified for CCA. The revision of CC related documents during this research revealed plans and policies with substantial content and applicable targets, but also climate strategies and plans with vague descriptions and critical omissions. As an example, although many municipal action plans and national strategies may refer to the importance of infrastructure and transport and state as main goals strengthening the connections with the global economy or increasing the competitiveness in the global markets, the port is in many cases absent from the document's content. This research could not incorporate these findings in the analysis and relate them to the relation between the port and the city, the respective governance patterns and the recorded adaptation responses. However, this association would provide meaningful outcomes.

As Hanson et al. (Hanson et al. 2010) mention, more in depth analysis is required especially regarding the most exposed locations. Except from identifying the points where policy could intervene, the current adaptation levels need to be identified and critically assessed, so that the uncertainties regarding the impacts of CC are reduced. This knowledge however, has to be combined with the wider research on climate and meteorological developments.

In addition, the cost of adaptation of port cities needs to be identified. This is the only way in which adaptation measures will become a concrete aspect of plans, with the opportunity to acquire funding and be implemented. Currently, there are global calculations regarding the costs and investment needs of CCA and CCM (UNFCCC 2007). However, although they provide us with very important information, they cannot support the adoption of actions on the local level, where adaptation will occur.

Finally, the relation and collaboration between the port and the city should always be apparent when any type of port city study is conducted. As Ducruet (n.d.) repeatedly recommends, the overall status of the port city has to be defined and examined within various fields of study, however always considering the dual nature and the separate functions of the port and city elements.

5.5 Epilogue

Climate Change is a new condition, a reality that cities need to accept and adapt to. However, as in every transitional situation, there are decisions to be made and opportunities that will actively define the possible outcomes. The agility of cities and the systems which they are part of will play the crucial role of defining the trajectories that they will follow under the new circumstances.

Port cities possess all the necessary resources to be among the “winners” of these circumstances, and lead urban transformation processes in an innovative manner, through integrated city management. The principal advantage in favour of port cities during this process, are the plenty of co-benefits of adaptation actions in a variety of sectors, from economy to social coherence.

To conclude, it can be reminded that even severe events like the melting of the Arctic are projected to provide opportunities such as faster sea navigation routes and the emergence of new marine clusters and development in unexpected locations. In an increasingly competitive and interconnected world, port cities owe to capitalize on their unique assets as well as on their risks, to build resilience, promote their economy and social coherence, and provide the world with developmental and managerial innovation. The focus should now be entirely on how this can be successfully implemented within the planet’s defined timeframes.

Bibliography

Aylett, A., 2014. *Progress and Challenges in the Urban Governance of Climate Change - Results of a global survey*, Cambridge.

Becker, A. et al., 2011. *Considering Climate Change: asurvey of global seaport administrators*,

Becker, A.A.H. et al., 2014. A note on climate change adaptation for seaports : A challenge for global ports , a challenge for global society. , pp.1–12.

Brookings Institute, 2014. Brookings. Available at: http://www.brookings.edu/research/interactives/global-metro-monitor-3 [Accessed September 2, 2014].

Cash, D.W. et al., 2006. Scale and Cross-Scale Dynamics : Governance and Information in a Multilevel World. , 11(2).

Castán Broto, V. & Bulkeley, H., 2013. A survey of urban climate change experiments in 100 cities. *Global Environmental Change*, 23, pp.92–102. Available at: http://ac.els-cdn.com/S0959378012000891/1-s2.0-S0959378012000891-main.pdf?_tid=a1c85304-c8d1-11e3-a6aa-00000aab0f01&acdnat=1398029024_01b2396465151fc620a3e3ca93f1a602.

Connecting Delta Cities, 2014. Connecting Delta Cities. Available at: http://www.deltacities.com/ [Accessed September 2, 2014].

Containerization International, 2014. *Top 100 container ports 2013*, Available at: http://europe.nxtbook.com/nxteu/informa/ci_top100ports2013/#/0.

Daamen, T. a. & Vries, I., 2013. Governing the European port–city interface: institutional impacts on spatial projects between city and port. *Journal of Transport Geography*, 27(2013), pp.4–13. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0966692312000762 [Accessed March 23, 2014].

Darbra, R.M. et al., 2005. A procedure for identifying significant environmental aspects in sea ports. *Marine pollution bulletin*, 50(8), pp.866–74. Available at: http://www.ncbi.nlm.nih.gov/pubmed/15946703 [Accessed April 16, 2014].

Darbra, R.M. et al., 2009. Survey on environmental monitoring requirements of European ports. *Journal of environmental management*, 90(3), pp.1396–403. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18929441 [Accessed April 9, 2014].

Delta Alliance, 2014. Delta Alliance. Available at: http://www.delta-alliance.org/ [Accessed September 2, 2014].

Demographia, 2014. *Demographia World Urban Areas (Built-Up Urban Areas or World Agglomerations) 10 th Annual Edition May 2014 Revision*, Ducruet, C., 2007. A metageography of port-city relationships.

Ducruet, C., 2011. Economic development paths of port-cities: specialization vs. diversification. , (June 2011).

Ducruet, C., *The port city in multidisciplinary analysis*,

Ducruet, C. & Lee, S.-W., 2006. Frontline soldiers of globalisation: Port–city evolution and regional competition. *GeoJournal*, 67(2), pp.107–122. Available at: http://link.springer.com/10.1007/s10708-006-9037-9 [Accessed March 23, 2014].

EBRD, 2011. *The EBRD and adaptation to climate change*, London.

Farhan, A.R. & Lim, S., 2013. Development of research framework for integrated coastal zone management. In *The 9th International Conference on Gi4DM Earth Observation for Disaster Management*. Hanoi, Vietnam, pp. 1–10.

Green, C.H. & Nicholls, R.J., 2010. Costs of adaptation to the effects of climate change in the world ' s large port cities.

HABITAT, U., 2011. *Cities and climate change*, London, Washington DC: Earthscan. Available at: http://books.google.com/books?hl=en&lr=&id=vdpxMNOfFDcC&oi=fnd&pg=PP1&dq=Cities+and+climate+change&ots=aTuHXraczY&sig=ZNFyYhYNvqZok4feeBbi2koIlpI [Accessed May 6, 2014].

Hanson, S. et al., 2010. A global ranking of port cities with high exposure to climate extremes. *Climatic Change*, 104(1), pp.89–111. Available at: http://link.springer.com/10.1007/s10584-010-9977-4 [Accessed March 19, 2014].

Hoyle, B.S., 1989. The port—City interface: Trends, problems and examples. *Geoforum*, 20, pp.429–435.

İleri, N. & Mansel, P., 2012. Rewriting the history of port cities in the light of contemporary global capitalism. *New perspectives on Turkey*, 47, pp.185–209. Available at: http://www.newperspectivesonturkey.net/Content/Npt/Issue_30/Lecture_30/185-209_47_NPT_Fall.pdf [Accessed May 6, 2014].

IPCC, 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:No+Title#0 [Accessed August 4, 2014].

Jacob, K., Gornitz, V. & Rosenzweig, C., 2007. Vulnerability of the New York City Metropolitan Area to Coastal Hazards , Including Sea-Level Rise : Inferences for Urban Coastal Risk Management and Adaptation Policies. , pp.0–8.

Lloyd’s list, 2014. Lloyd’s list. Available at: http://directories.lloydslist.com/ [Accessed August 10, 2014].

Luo, M. & Yip, T.L., 2013. Ports and the environment. *Maritime Policy & Management*, 40(5), pp.401–403. Available at: http://www.tandfonline.com/doi/abs/10.1080/03088839.2013.797122 [Accessed April 16, 2014].

Merk, O., 2013. *The Competitiveness of Global Port-Cities : Synthesis Report*,

Merk, O. & Dang, T.-T., 2013. *The Effectiveness of Port-City Policies : A comparative approach*, Paris.

Molenaar, A. et al., 2014. *Connecting Delta Cities - resilient cities and climate adaptation strategies*,

Moncuit, L. de, 2013. *2013 Annual Report: local response to measurable, reportable, verifiable global climate action*,

Naruse, S., 2011. *Ad Hoc Expert Meeting on Climate Change Impacts and Adaptation : A Challenge for Global Ports Climate Change Impacts – Adaptation Measures in Ports – Climate Change Impacts -Adaptation Measures in Ports-*,

Ng, A.K.Y. et al., 2013. Climate change and the adaptation strategies of ports: the Australian experiences. *Research in Transportation Business & Management*, 8(2013), pp.186–194. Available at: http://linkinghub.elsevier.com/retrieve/pii/S2210539513000643 [Accessed June 22, 2014].

Nicholls, R.J. et al., 2008. Ranking port cities with high exposure and vulnerability to climate extremes. *OECD working paper*.

Nursey-Bray, M. et al., 2013. Vulnerabilities and adaptation of ports to climate change. *Journal of Environmental Planning and Management*, 56, pp.1021–1045. Available at: http://www.tandfonline.com/doi/abs/10.1080/09640568.2012.716363.

Peris-Mora, E. et al., 2005. Development of a system of indicators for sustainable port management. *Marine pollution bulletin*, 50(12), pp.1649–60. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16095626 [Accessed April 7, 2014].

Pesquera, M. & Ruiz, J., 1996. *Sustainable development strategies for cities and ports*, New York and Geneva. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Sustainable+development+strategies+for+cities+and+ports#1 [Accessed April 29, 2014].

PIANC, 2010. Climate Change and Navigation: Waterborne transport, ports and waterways. A review of climate change drivers, impacts, responses and mitigation. *Permanent International Association of Navigation Congresses*.

Post, J.C. & Lundin, C.G., 1996. Guidelines for integrated coastal zone management. *World Bank*.

Satterthwaite, D., McGranahan, G. & Tacoli, C., 2010. Urbanization and its implications for food and farming. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 365(1554), pp.2809–20. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2935117&tool=pmcentrez&rendertype=abstract [Accessed July 13, 2014].

Scott, H. et al., 2008. Climate change adaptation guidelines for ports. *National Climate Change Adaptation Research Facility*. Available at: http://medcontent.metapress.com/index/A65RM03P4874243N.pdf [Accessed April 18, 2014].

Source, W.P., 2014. World Port Source. Available at: http://www.worldportsource.com/.

Tompkins, E.L. & Adger, W.N., 2001. Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change ? *Ecology and society*, 9(2).

Tongzon, J. & Heng, W., 2005. Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminals). *Transportation Research Part A: Policy and Practice*, 39(5), pp.405–424. Available at: http://linkinghub.elsevier.com/retrieve/pii/S096585640500025X [Accessed March 25, 2014].

UN Habitat, 2008. *Meeting the urban challenges*, Seville. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3760319&tool=pmcentrez&rendertype=abstract.

UNCTAD, 2011. Ad Hoc Expert Meeting on Climate Change Impacts and Adaptation : A Challenge for Global Ports. In Geneva.

UNDP, 2014. *Human development report 2014, Sustaining human progress: reducing vulnerabilities and building resilience.*, New York. Available at: http://hdr.undp.org/sites/default/files/hdr14-report-en-1.pdf.

UNFCCC, 2011. Assessing climate change impacts and vulnerability - Making informaed adaptation decisions. *United Nations Framework Convention on Climate Change*.

UNFCCC, 2007. *Investment and financial flows to address climate change*, Bonn. Available at: http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Investment+and+financial+flows+to+address+climate+change#1 [Accessed April 29, 2014].

World Bank, 2012. *Building Urban Resilience: Principles, Tools, and Practice*, Washington DC. Available at: http://books.google.com/books?hl=en&lr=&id=bVYyinp6KoUC&oi=fnd&pg=PP1&dq=Building+urban+resilience:+principles,+tools+and+practice&ots=kmXYqzxsax&sig=s-oHG5K7utxZ6C3jXV0MrsWwMPg [Accessed April 29, 2014].

Annex 1

Availability of data for the selected port cities, and city names of the entries in each source

City	Country	Continent	**Exposure** (Hanson et al. 2010)	**RCI** (Ducruet & Lee 2006)	cCCR
Baltimore Maryland	USA	North America	X	X	X
Barcelona	Spain	Europe	X	X	X
Boston Massachusetts	USA	North America	X	X	X
Buenos Aires	Argentina	South America	X	X	X
Cape Town	South Africa	Africa	X	X	X
Cochin (Kochi)	India	Asia	X	X	X
Copenhagen	Denmark	Europe	X	Copenhagen - Malmo	X
Dar es Salaam	Tanzania	Africa	X	X	X
Durban	South Africa	Africa	X	X	X
Fortaleza (Ceara)	Brazil	South America	X	X	X
Hiroshima	Japan	Asia	X	X	X
Houston Texas	USA	North America	X	X	X
Istanbul	Turkey	Asia	X	Haydarpasa - Istanbul	X
Keelung	Taiwan	Asia	-	Keelung - Taipei	-
Kobe	Japan	Asia	Osaka - Kobe	Osaka - Kobe	X
Lima	Peru	South America	X	Callao - Lima	X
Lisbon	Portugal	Europe	X	X	X
Long Beach California	USA	North America	Los Angeles - Long Beach Santa Ana	Los Angeles - Long Beach	X
Los Angeles California	USA	North America	Los Angeles - Long Beach Santa Ana	Los Angeles - Long Beach	X
Malmo	Sweden	Europe	-	Copenhagen - Malmo	X
Melbourne	Australia	Australia	X	X	X
Miami Florida	USA	North America	X	Miami - Port Everglades	X
Montreal	Canada	North America	X	X	X
Nagoya	Japan	Asia	X	X	X
New Orleans Louisiana	USA	North America	X	X	X
New Taipei	Taiwan	Asia	Taipei	Keelung - Taipei	X
Oakland California	USA	North America	San Fransisco - Oakland	Oakland - San Fransisco	X
Osaka	Japan	Asia	Osaka - Kobe	Osaka - Kobe	prefectural government
Portland Oregon	USA	North America	X	X	X
Porto Alegre	Brazil	South America	X	X	X
Recife	Brazil	South America	X	X	X
Rio de Janeiro	Brazil	South America	X	X	X
San Fransisco California	USA	North America	San Fransisco - Oakland	Oakland - San Fransisco	X
Seattle Washington	USA	North America	X	Seattle - Tacoma	X
Stockholm	Sweden	Europe	X	X	X
Tacoma Washington	USA	North America	-	Seattle - Tacoma	X
Taipei	Taiwan	Asia	Taipei	Keelung - Taipei	X
Tokyo	Japan	Asia	X	Tokyo - Yokohama	X
Vancouver	Canada	North America	X	X	X
Yokohama	Japan	Asia	-	Tokyo - Yokohama	X

Annex 2

Ports, TEUs and Top 100 container ports globally ranking (alphabetical order)

Port	TEUs handled in 2012	Top 100 container ports ranking
Baltimore Maryland	677876	-
Barcelona	1756429	77
Boston Massachusetts	187747	-
Buenos Aires	1656000	79
Cape Town	1572635	92
Cochin (Kochi)	334925	-
Copenhagen	148000	-
Dar es Salaam	475000	-
Durban	2529404	55
Fortaleza (Ceara)	41590	-
Hiroshima	-	-
Houston Texas	1922529	71
Istanbul	3097464	42
Keelung	2704730	49
Kobe	2567540	52
Lima	1817663	76
Lisbon	17404	-
Long Beach California	6045662	22
Los Angeles California	8077714	16
Malmo	475000	-
Melbourne	2547623	53
Miami Florida	909197	-
Montreal	1375327	-
Nagoya	2655225	50
New Orleans Louisiana	464834	-
Oakland California	2344392	58
Osaka	2409754	57
Portland Oregon	183202	-
Porto Alegre	-	-
Recife	2149	-
Rio de Janeiro	332331	-
San Fransisco California	-	-
Seattle Washington	1885680	73
Stockholm	36000	-
Tacoma Washington	1711133	78
Taipei / New Taipei	-	-
Tokyo	4751653	28
Vancouver	2713160	48
Yokohama	-	-

Selected port cities, population and population density (alphabetical order)

City	Population	Population density (inhabitants / sqkm)
Baltimore Maryland	619493	2598,5
Barcelona	5529099	6885,6
Boston Massachusetts	636479	2742,3
Buenos Aires	2890151	14279,4
Cape Town	3740025	1523,4
Cochin (Kochi)	601574	6340,4
Copenhagen	559440	6339,3
Dar es Salaam	4364541	2744,1
Durban	3442361	1498,6
Fortaleza (Ceara)	3597000	11462,7
Hiroshima	1185814	1309,7
Houston Texas	2160000	1329,2
Istanbul	12915158	2417,2
Keelung	2618772	9627,8
Kobe	1545410	2800,0
Lima	7605742	2846,5
Lisbon	547631	7457,9
Long Beach California	462257	3548,8
Los Angeles California	3857799	3176,0
Malmo	280415	9460,0
Melbourne	93625	2586,3
Miami Florida	413892	2892,3
Montreal	1886481	3773,0
Nagoya	2262176	6930,0
New Orleans Louisiana	378715	810,0
New Taipei	3893740	15200,0
Oakland California	406253	6819,1
Osaka	2666371	11836,0
Portland Oregon	583776	1350,0
Porto Alegre	1409351	2841,4
Recife	1537704	7133,2
Rio de Janeiro	6429923	5253,2
San Fransisco California	837442	1983,9
Seattle Washington	608660	1718,7
Stockholm	881235	4079,8
Tacoma Washington	198397	1223,9
Taipei	2693672	15200,0
Tokyo	13185502	6029,0
Vancouver	603502	5262,9
Yokohama	3697894	8500,0

Selected port cities and their RCI in descending order (source: (Ducruet & Lee 2006)

Port city	RCI
Durban	2,23
Seattle Washington	1,67
Tacoma Washington	1,67
Miami Florida	1,47
Vancouver	1,4
Long Beach California	1,38
Los Angeles California	1,38
Montreal	1,27
Houston Texas	1,21
New Orleans Louisiana	1,19
Melbourne	1,11
Cochin (Kochi)	1,04
Cape Town	0,57
Oakland California	0,51
San Fransisco California	0,51
Barcelona	0,47
Lima	0,46
Buenos Aires	0,43
Keelung	0,43
New Taipei	0,43
Taipei	0,43
Nagoya	0,42
Baltimore Maryland	0,37
Kobe	0,37
Osaka	0,37
Lisbon	0,3
Tokyo	0,28
Yokohama	0,28
Dar es Salaam	0,26
Portland Oregon	0,26
Rio de Janeiro	0,26
Recife	0,25
Copenhagen	0,22
Fortaleza (Ceara)	0,22
Malmo	0,22
Hiroshima	0,15
Boston Massachusetts	0,1
Porto Alegre	0,08
Stockholm	0,08
Istanbul	0,06

Annex 3

The questions of the questionnaire ranked according to the positive responses number

Question	Positive Responses
Is there continuous monitoring of infrastructure conditions?	11
Are the storages suitable for wide temperature range?	10
Does the port have a weather station measuring climate change variables?	10
Is there an emergency preparedness and response system?	10
Can storage facilities that accommodate extreme climate events?	9
Is climate change being considered in future design specifications for buildings and infrastructure?	9
Does Port Authority cooperate with the local (municipal) government on climate change adaptation?	9
Are there drainage systems that can cope with projected rain events?	8
Has the port conducted a "Climate change risk assessment"?	8
Is there a "Cyclone / Hurricane / Storm response plan"?	8
Does the port use technological equipment with durability to climate extremes?	7
Is climate change a consideration for procurement of assets?	7
Are there dust suppression systems?	7
Are port elevations raised to respond to flooding issues?	7
Are there alternative routes or transport modal shift in the supply system?	7
Is there insurance against risks that the Port Authority is unable to reduce?	7
Does the port cooperate with ports that are at the forefront of climate extremes for knowledge exchange?	7
Is the relocation the port or part of the facilities a consideration?	6
Does land use planning control the use of flood prone areas?	6
Is quantification of climate change impacts being done?	6
Is there a "Port climate adaptation plan"?	6
Are roadways or rail tracks raised to respond to flooding issues?	5
Is policy upgraded to include consideration of climate change impacts?	5
Is there a "Port climate change policy / strategy"?	5
Are adaptation actions embedded in emergency procedures and risk management?	5
Is there automation of logistics procedures?	4
Is incremental growth of breakwaters being considered?	4
Are there water retention basins to gather water during flooding?	4
Does the port work in partnership with the city government to plan/design connection to logistics hubs resilient to impacts of climate change in the area?	4
Are port climate adaptation guidelines included in (national) governmental plans?	4
Is there onsite renewable and low emission energy production?	3
Is there a "Fatigue response plan"?	3
Is diversification of trade into climate resilient commodities a plan of the port?	1
Is training on climate change a part of training elements?	1

Responses of the ports to the questionnaire survey

Question	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Baltimore Maryland	Landlord port type management	Y	N	Y	N	Y	Y	N	N	O	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	Y	N	Y	Y	-	Y	Y	Y	Y
Boston Massachusetts	Public: regional port	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y
Cochin (Kochi)	Public: national port, Public: regional port	Y	Y	N	N	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	Y	N	N	N	N	Y	Y	N	N	N	Y	Y	Y	Y
Copenhagen	Private - public, Private	N	Y	N	N	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y
Lima	Public: national port	N	Y	N	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	Y	N	Y	N	N	Y	N	N	Y	N	N	N	N	Y	Y	N	N
Lisbon	Landlord port type management	Y	Y	N	-	Y	Y	Y	Y	N	N	N	N	-	Y	-	-	Y	Y	Y	N	Y	-	Y	N	-	N	N	N	-	-	-	-	O
Long Beach California	Public: municipal port	N	-	N	N	N	-	Y	Y	N	Y	Y	N	-	O	Y	-	N	Y	Y	O	O	-	O	N	Y	Y	O	O	O	-	-	N	Y
Los Angeles California	Public: municipal port	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	Y	O	Y	Y	N	N	Y	Y	Y	Y	O	N	N	Y	Y	Y	Y	N	N	N	N	Y
Malmo	Private - public, Private	Y	Y	N	N	Y	Y	Y	N	N	N	Y	N	Y	Y	Y	N	N	N	N	Y	N	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y
Melbourne		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Montreal	Public: national port	Y	Y	N	N	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	N	N	N	Y
Osaka	Public: municipal port	N	Y	N	Y	N	N	Y	N	N	Y	Y	Y	Y	N	Y	N	Y	N	Y	N	N	N	N	N	N	Y	N	N	N	N	Y	O	O
Porto Alegre	Public: national port	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	-	N	N	-	-	N	N	-	-	N	N	Y
Seattle Washington	Public: regional port	N	Y	N	N	Y	Y	N	N	O	N	O	N	Y	Y	Y	O	N	Y	O	Y	Y	Y	O	O	Y	Y	Y	N	Y	N	Y	N	N

Annex 4

Adopted actions per type, as they are enlisted in cCCR, for the 40 cities.

City	Total Adaptation Actions	Action Plan / Report	Coastal Zones / Marine Ecosystems	Early Warning Systems / Disaster Manageme	Food Security	Health	Infrastructu re	Terrestrial Ecosystems	Water Resources
Baltimore	2	0	0	1	0	0	0	1	0
Barcelona	3	0	0	0	0	0	0	1	2
Boston	1	1	0	0	0	0	0	0	0
Buenos Aires	12	0	1	1	0	1	1	7	1
Cape Town	4	2	2	0	0	0	0	0	0
Cochin	2	1	0	0	0	0	1	0	0
Copenhagen	3	0	0	0	0	0	1	0	2
Dar es Salaam	4	1	2	0	0	0	0	1	0
Durban	28	8	1	0	2	0	0	14	3
Fortaleza	0	0	0	0	0	0	0	0	0
Hiroshima	0	0	0	0	0	0	0	0	0
Houston Texas	6	1	0	0	0	3	0	1	1
Istanbul	5	1	0	1	0	1	0	0	2
Keelung	0	0	0	0	0	0	0	0	0
Kobe	0	0	0	0	0	0	0	0	0
Lima	3	0	0	0	1	0	1	1	0
Lisbon	2	0	0	0	1	0	0	0	1
Long Beach	0	0	0	0	0	0	0	0	0
Los Angeles	3	1	1	0	0	0	0	1	0
Malmo	1	0	0	0	0	0	0	0	1
Melbourne	3	0	0	0	0	1	0	1	1
Miami Florida	5	1	0	1	0	0	3	0	0
Montreal	10	5	0	0	0	0	0	3	2
Nagoya	3	0	0	1	0	0	0	1	1
New Orleans	0	0	0	0	0	0	0	0	0
New Taipei	5	0	0	3	0	1	1	0	0
Oakland	2	0	1	0	0	0	0	0	1
Osaka	0	0	0	0	0	0	0	0	0
Portland Oregon	0	0	0	0	0	0	0	0	0
Porto Alegre	0	0	0	0	0	0	0	0	0
Recife	0	0	0	0	0	0	0	0	0
Rio de Janeiro	3	1	0	0	0	2	0	0	0
San Francisco	5	1	0	0	3	0	0	0	1
Seattle	9	0	1	0	0	2	2	3	1
Stockholm	8	0	1	0	0	3	0	3	1
Tacoma	1	1	0	0	0	0	0	0	0
Taipei	4	1	0	1	0	1	0	0	1
Tokyo	1	1	0	0	0	0	0	0	0
Vancouver	7	1	2	0	1	0	2	1	0
Yokohama	0	0	0	0	0	0	0	0	0

Adaptation actions of selected cities according to the cCCR

City	Actions	Sector	Financing
City of Baltimore	Tree Baltimore - Increase the number of trees planted	Terrestrial Ecosystems	
	Disaster Preparedness & Planning Project Plan	Early Warning Systems and Disaster management	
Barcelona Metro-Area Authority (DIBA)	Forest Management at the Barcelona Regional Natural Park Network	Terrestrial Ecosystems	Local
	Local Governments United to Fight Drought	Water Resources	Local
	Citizen Awareness Campaign: “La red ahorra agua” (“The Water-Saving Network”)	Water Resources	Local
City of Boston	City of Boston Mitigation Report	Action Plan / Report / Research	
Ciudad Autónoma de Buenos Aires	Urban Green Corridors as Part of Buenos Aires’s Territorial Model	Terrestrial Ecosystems	Local
	Severe Rain Adaptations: Long-Tunnel Improvements at Arroyo Maldonado, Rainwater Runoff Systems and Lakes as Flood Buffers	Terrestrial Ecosystems	Local
	Monitoring the French y Beruti School Green Roof	Infrastructure	Local
	Designing Urban Green corridors	Terrestrial Ecosystems	Local
	Reducing the risk of \"Dengue\" disease	Health	Local
	Riachuelo River Bank	Coastal zones/Marine Ecosystems	Local
	Meteorological Network	Early Warning Systems and Disaster management	Local
	Adapting to heavier rains	Water Resources	Local
	Urban tree program -stage 1	Terrestrial Ecosystems	Local
	Green walls	Terrestrial Ecosystems	Local
	Green Roofs - stage 2	Terrestrial Ecosystems	Local
	Green Roofs - stage 1	Terrestrial Ecosystems	Local
City of Cape Town	Climate Chnage Think Tank	Action Plan / Report / Research	International (ODA)
	Climate Adaptation Plan of Action (CAPA)	Action Plan / Report / Research	Local
	Coastal Edge and Coastal Protection Zone	Coastal zones/Marine Ecosystems	Local
	Sea level Rise Risk Assessment	Coastal zones/Marine Ecosystems	Local
Cochin Municipal Corporation	Service Level Benchmarking of Indian Cities	Action Plan / Report / Research	
	Asian Cities Adapt	Infrastructure	
City of Copehagen	Restoration of Harrestrup stream	Water Resources	Local
	Severe Storm Anti-Flooding Initiatives (The Vilhelmdal Drainage System)	Water Resources	Local
	Sankt Kjelds City District	Infrastructure	Local
City of Dar es Salaam	Dar es Salaam Adaptive Structures Construction	Coastal zones/Marine Ecosystems	International (ODA)
	Kinondoni Integrated Coastal Area Management Project (KICAMP	Coastal zones/Marine Ecosystems	International (ODA)
	Sub Saharan African Cities: A Five-City Adaptation Network to Pioneer Climate Change Adaptation through Participatory Research and Local Action	Action Plan / Report / Research	International (ODA)
	Reforestation and Mangrove Restoration	Terrestrial Ecosystems	Local
eThekwini Municipality	Durban Adaptation Charter	Action Plan / Report / Research	Local
	Development of the combined Adaptation and Mitigation Strategy	Action Plan / Report / Research	Local
	Durban Community Ecosystem Based Adaptation (CEBA)	Terrestrial Ecosystems	Local
	Durban Botanic Gardens: A Climate Change and Biodiversity Awareness Centre of Excellence	Terrestrial Ecosystems	Local
	Sliding Scale of Tariffs	Water Resources	Local
	eThekwini Municipality Systematic Conservation Plan	Terrestrial Ecosystems	Local

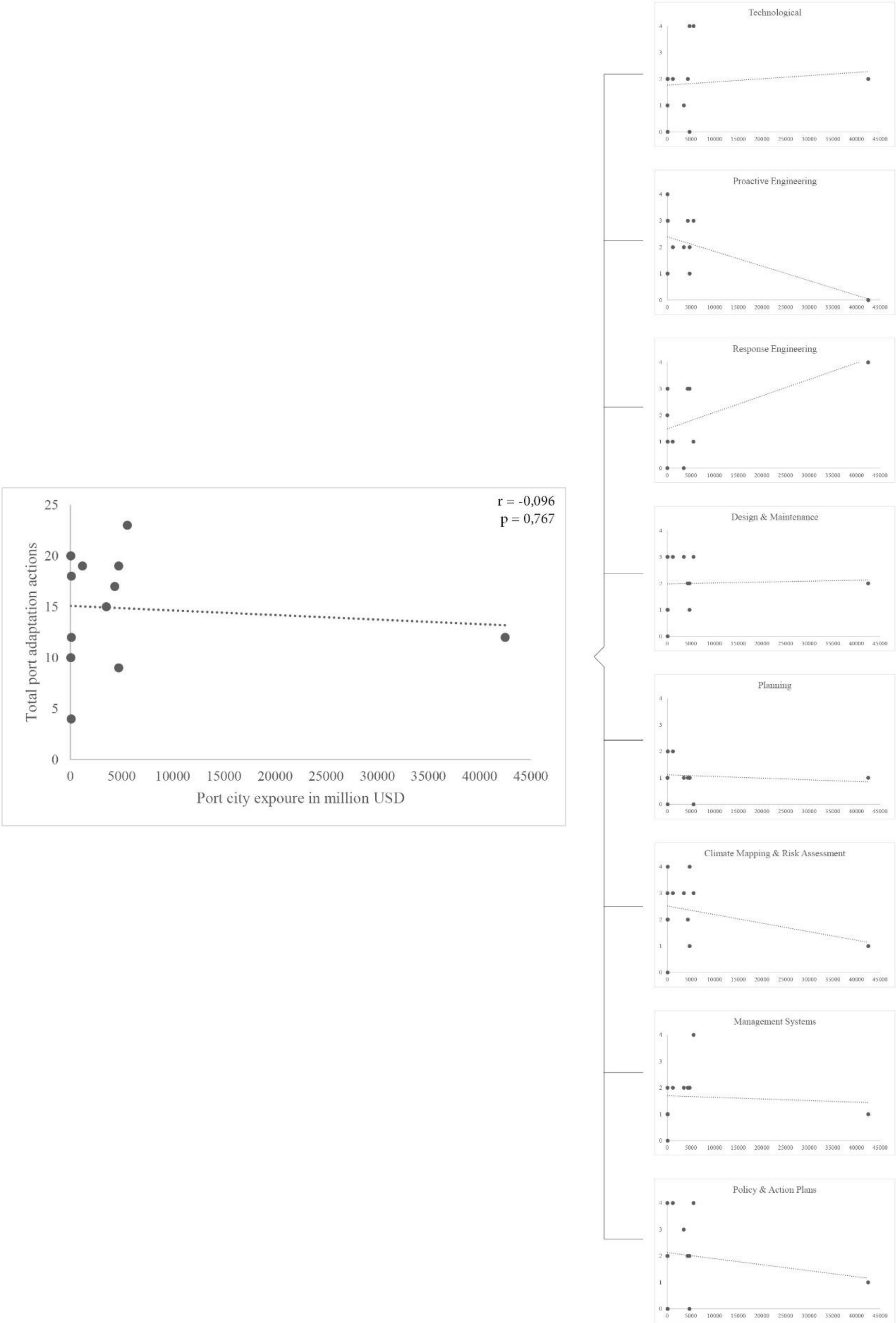
	Paradise Valley Reforestation Project	Terrestrial Ecosystems	Local
	Inanda Mountain Reforestation Project	Terrestrial Ecosystems	Local
	Mariannhill Landfill Conservancy	Terrestrial Ecosystems	Local
	Luganda School Water Harvesting and Micro Agricultural Water Management Technology	Food Security	Local
	Sihlanzimvelo Project	Water Resources	Local
	Municipal Adaptation Plan for Climate Change	Action Plan / Report / Research	Local
	The Integrated Assessment Tool for Climate Change Adaptation	Action Plan / Report / Research	Local
	Municipal Adaptation Plans Cost-Benefit Analysis	Action Plan / Report / Research	Local
	Non-User Conservation Servitudes (NUCS)	Terrestrial Ecosystems	Local
	Sea level rise assessment	Coastal zones/Marine Ecosystems	Local
	Low Carbon Durban Research Project	Action Plan / Report / Research	Local
	Green Roof Pilot Project	Terrestrial Ecosystems	Local
	Durban Climate Change Partnership (DCCP)	Action Plan / Report / Research	Local
	Community Adaptation Plans (CAPs)	Food Security	Local
	Buffelsdraai Landfill Site Community Reforestation Project	Terrestrial Ecosystems	Local
	Durban Water Recycling	Water Resources	Local
	Working on Fire	Terrestrial Ecosystems	Local
	Working for Ecosystems	Terrestrial Ecosystems	Local
	Invasive Alien Plant (IAP) Control Programme	Terrestrial Ecosystems	Local
	Green Guideline Series	Action Plan / Report / Research	Local
	Durban Green Corridor	Terrestrial Ecosystems	Local
	Durban Metropolitan Open Space (D'MOSS): Planning and Implementation	Terrestrial Ecosystems	Local
Municipality of Fortaleza	-		
Hiroshima City	-		
City of Houston	Bayou Greenways Initiative	Terrestrial Ecosystems	
	Urban Grows	Health	Local
	Mobile Refridgeration Units	Health	Local
	Water Conservation Campaign	Water Resources	Local
	White Roofs	Health	Local
	Heat Emergency Plan - Cooling Centers	Action Plan / Report / Research	Local
Istanbul Metropolitan Municipality	Istanbul Energy Policies and CO2 reduction in the metropolitan	Action Plan / Report / Research	International (ODA)
	Monitoring Gas Consumption for Thermo-rehabilitation of Residential Buildings	Health	International (ODA)
	Ayamama Creek Rehabilation	Water Resources	(Sub) National
	impacts of climate change on water resources in İstanbul	Water Resources	(Sub) National
	development of a GIS-based decision support system for urban air quality management	Early Warning Systems and Disaster management	International (ODA)
Keelung City Government	-		
Kobe City	-		
Municipalidad Metropolitana de Lima	Barrio Mío Program	Infrastructure	Local
	Mi Huerta Program	Food Security	Local
	Lima Verde Program	Terrestrial Ecosystems	(Sub) National
Camara Municipal de Lisboa	Urban Agriculture Program	Food Security	Local
	Reducing Public Space Water Demand	Water Resources	Public Private Partnership
City of Long Beach	-	-	
City of Los Angeles	Climate Adaptation Plan – AdaptLA: Sea Level Rise Vulnerability Assessment	Coastal zones/Marine Ecosystems	Local
	AdaptLA Climate Forecasting Studies	Action Plan / Report / Research	Local
	50 Parks Initiative	Terrestrial Ecosystems	Local
Malmo Stad	Open Stormwater System in Fosie Industrial Area	Water Resources	Local

City of Melbourne	ArtPlay White Roofy	Health	Local
	Urban Forest Strategy	Terrestrial Ecosystems	Local
	Stormwater Harvesting in Fitzroy Gardens	Water Resources	Local
City of Miami	Miami Climate Action Plan	Action Plan / Report / Research	
	Hurricane Plan	Early Warning Systems and Disaster management	
	Greenspace Requirements	Infrastructure	
	Heat Island Effect Ordinance for Non-Roofs	Infrastructure	
	Heat Island Effect Ordinance for Roofs'	Infrastructure	
Ville de Montréal	By-law CMM-2001-10	Action Plan / Report / Research	Local
	Parks and green space improvement program	Terrestrial Ecosystems	Local
	Environmental protection for green spaces	Terrestrial Ecosystems	Local
	Strategic plan for public safety	Action Plan / Report / Research	Local
	Montreal Community Sustainable Development Plan 2010 - 2015	Action Plan / Report / Research	Local
	Urban management scheme	Action Plan / Report / Research	Local
	Improving and protecting the water quality of local water bodies	Water Resources	Local
	Augmenting the urban tree canopy cover	Terrestrial Ecosystems	Public Private Partnership
	Improving stormwater management	Water Resources	Local
	Climate change adaptation plan for the Montreal community	Action Plan / Report / Research	(Sub) National
City of Nagoya	Area Greenification System	Early Warning Systems and Disaster management	Local
	Improved Rainwater Absorption	Water Resources	Local
	Green Space Program	Terrestrial Ecosystems	Local
City of New Orleans	-		
New Taipei City	Infectious Diseases Prevention Plan	Health	Local
	Disaster Prevention Park Promotion and Construction	Early Warning Systems and Disaster management	Local
	Disaster Prevention and Response Intensive Plan	Early Warning Systems and Disaster management	Local
	Building Disaster Warning System	Early Warning Systems and Disaster management	Local
	Reconstruction of Zhonggang Main Drainage River Corridor Plan	Infrastructure	Local
City of Oakland	Install Infrastructure to Reduce Flood Impacts	Water Resources	
	Study Potential Local Climate Impacts	Coastal zones/Marine Ecosystems	
Osaka Prefectural Government	-		
City of Portland	-		
The Municipality of Porto Alegre	-		
Prefeitura do Recife	-		
Município do Rio de Janeiro / Municipality of Rio de Janeiro	Plano de emergência para chuvas fortes da Defesa Civil	Action Plan / Report / Research	Local
	Centro de Operações Rio	Health	Local
	n City Population Climate-Change-Related Health Vulnerabilities	Health	Local
City of San Fransisco	Climate Resilient SF	Action Plan / Report / Research	Local
	SF Carbon Fund	Food Security	Public Private Partnership
	Local Water Supply Program	Water Resources	Local
	Urban Agriculture	Food Security	Local

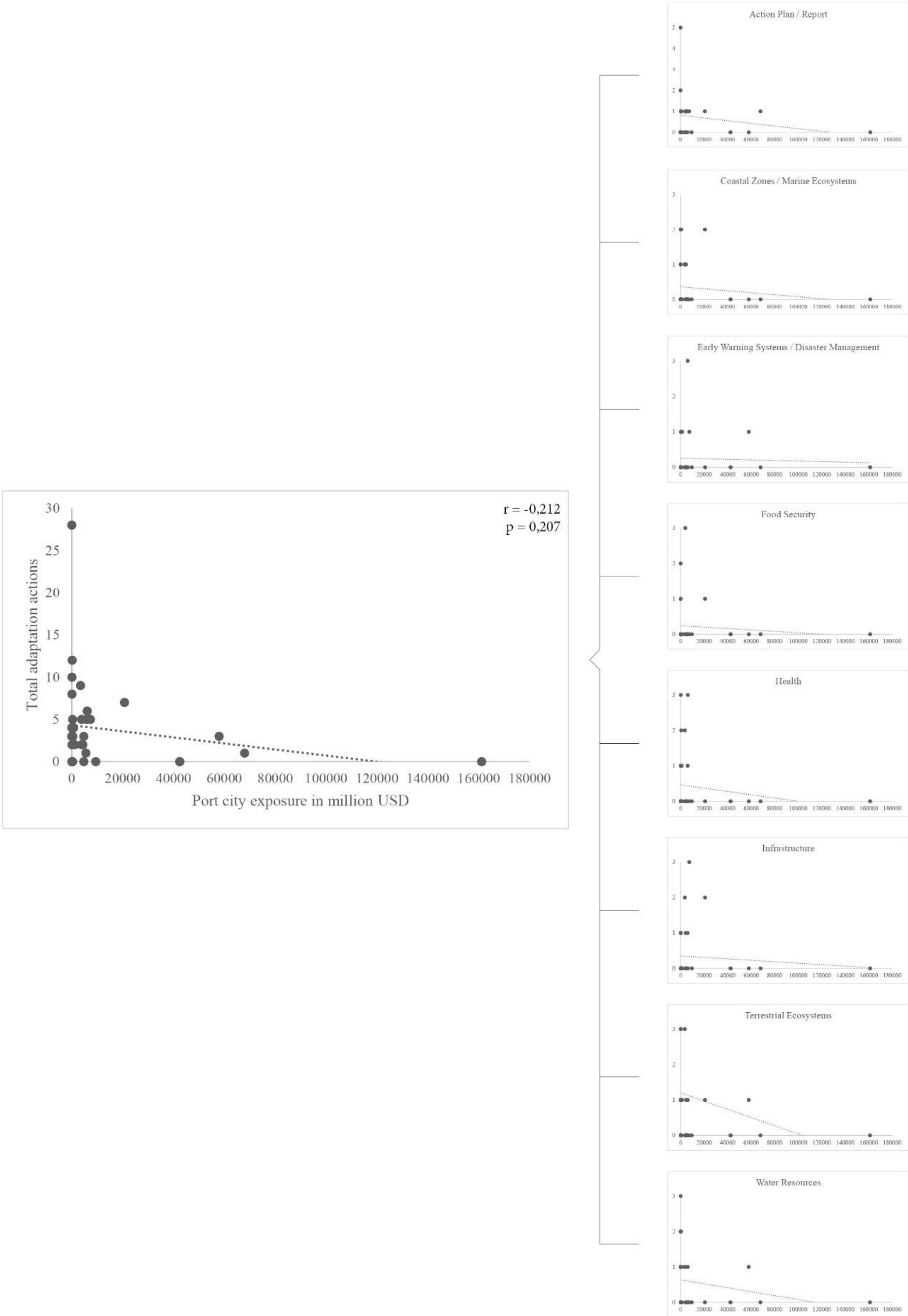
	Healthy and Sustainable Foods mandate	Food Security	Local
City of Seattle	Climate Research on City-owned Watersheds	Terrestrial Ecosystems	
	Seattle RainWatch	Infrastructure	
	2009 Flood-prone Areas Mapping	Terrestrial Ecosystems	
	Stormwater Code Update	Infrastructure	
	Disaster Preparedness Materials	Health	
	Community Communication Network	Health	
	Water Conservation	Water Resources	
	Inundation Mapping	Coastal zones/Marine Ecosystems	
	Seattle Community ReLeaf	Terrestrial Ecosystems	Local
City of Stockholm	Urban Ecosystem Services	Health	(Sub) National
	Sea levels in Stockholm	Coastal zones/Marine Ecosystems	Local
		Health	Local
	Radiation temperatures in Stockholm	Health	Local
	Climate Adaptation in Review Plan	Terrestrial Ecosystems	Local
	Climate Adaption in the Park Program	Terrestrial Ecosystems	Local
	Development of green space factor for blocks of land in Stockholm Royal Seaport	Terrestrial Ecosystems	Local
	New Regulation of Mälaren, reconstruction of Slussen	Water Resources	(Sub) National
City of Tacoma	Tacoma Climate Turnaround	Action Plan / Report / Research	Local
Taipei	Overall target and framework for flooding protection	Water Resources	(Sub) National
	Taipei city Typhoon and flooding crisis emergency plan	Early Warning Systems and Disaster management	Local
	Taipei city 2010-2011 Dengue Fever control plan	Health	Local
	Taipei city heat island effect mitigation plan	Action Plan / Report / Research	Local
Tokyo Metropolitan Government	Comprehensive Climate Change Impact-Evaluation Studies	Action Plan / Report / Research	Local
City of Vancouver	Climate Adaptation Plan	Action Plan / Report / Research	(Sub) National
	Support and expand extreme heat planning	Coastal zones/Marine Ecosystems	
	Develop and implement a comprehensive Urban Forest Management Plan	Terrestrial Ecosystems	
	West House Demonstration Project	Infrastructure	Public Private Partnership
	Van Dusen Gardens Living building	Infrastructure	Local
	Clouds of Change Task Force	Coastal zones/Marine Ecosystems	
	Vancouver Food Strategy	Food Security	
City of Yokohama	-		

Annex 5

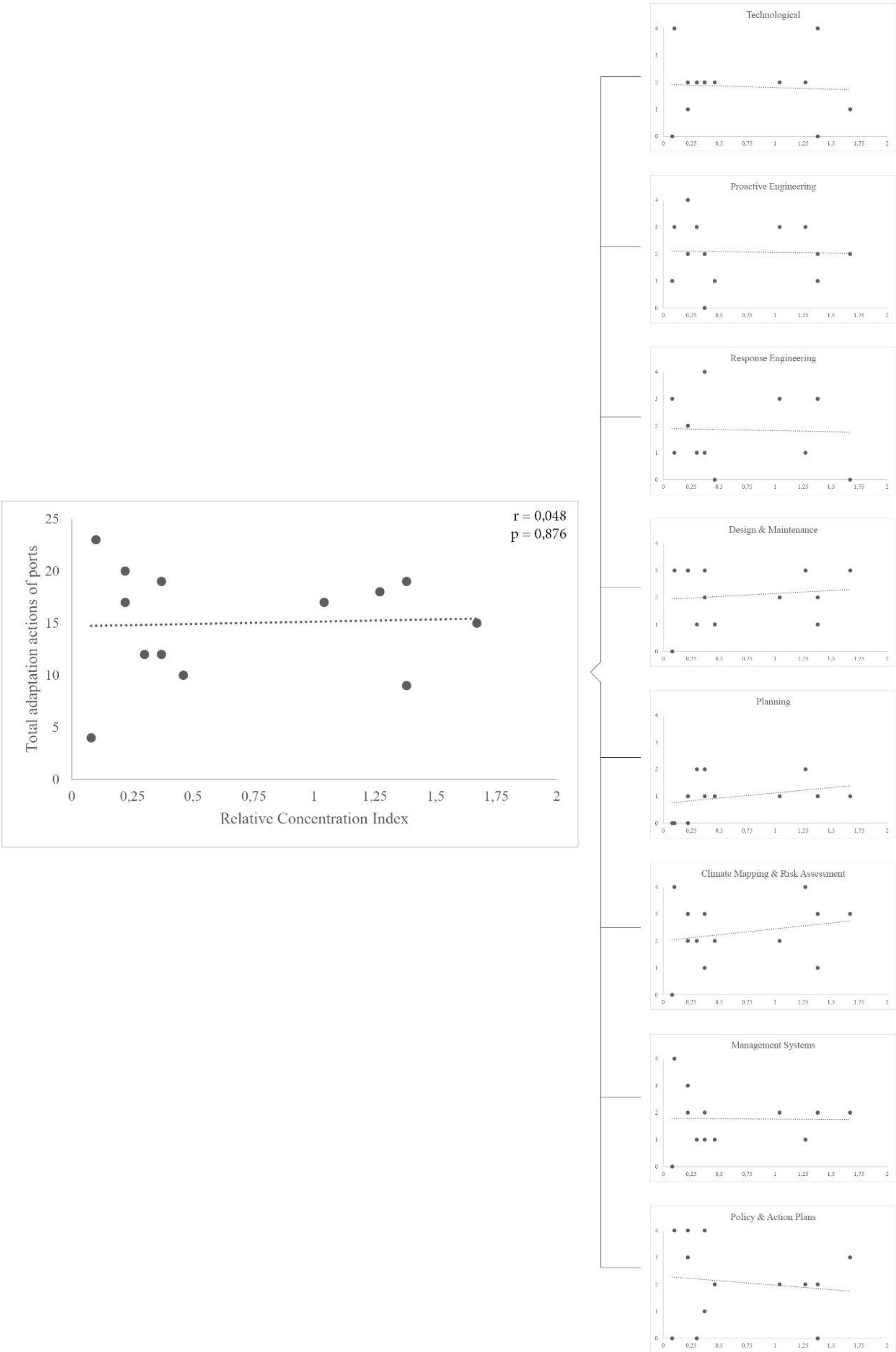
Port city exposure – port actions



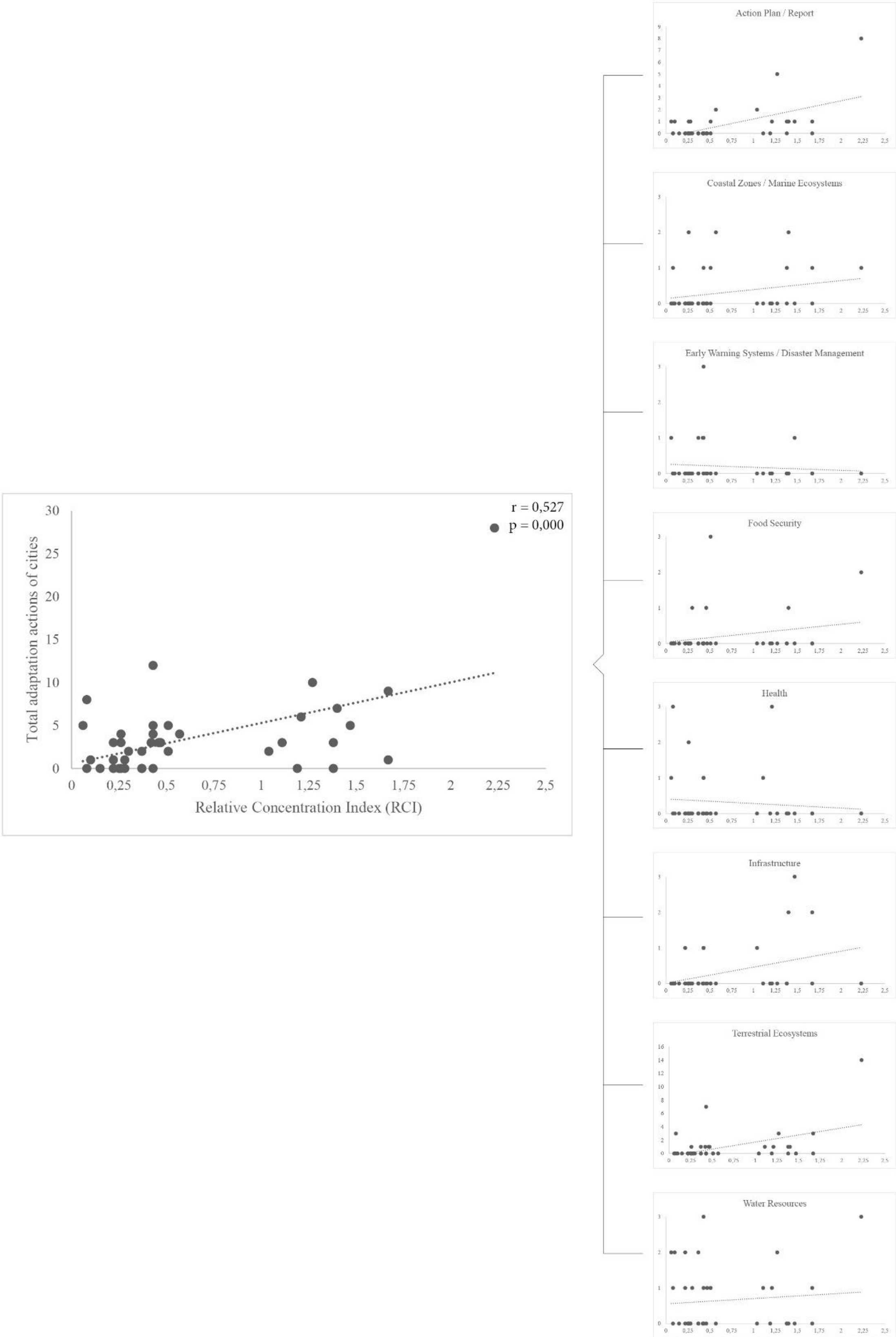
Port city exposure – city actions



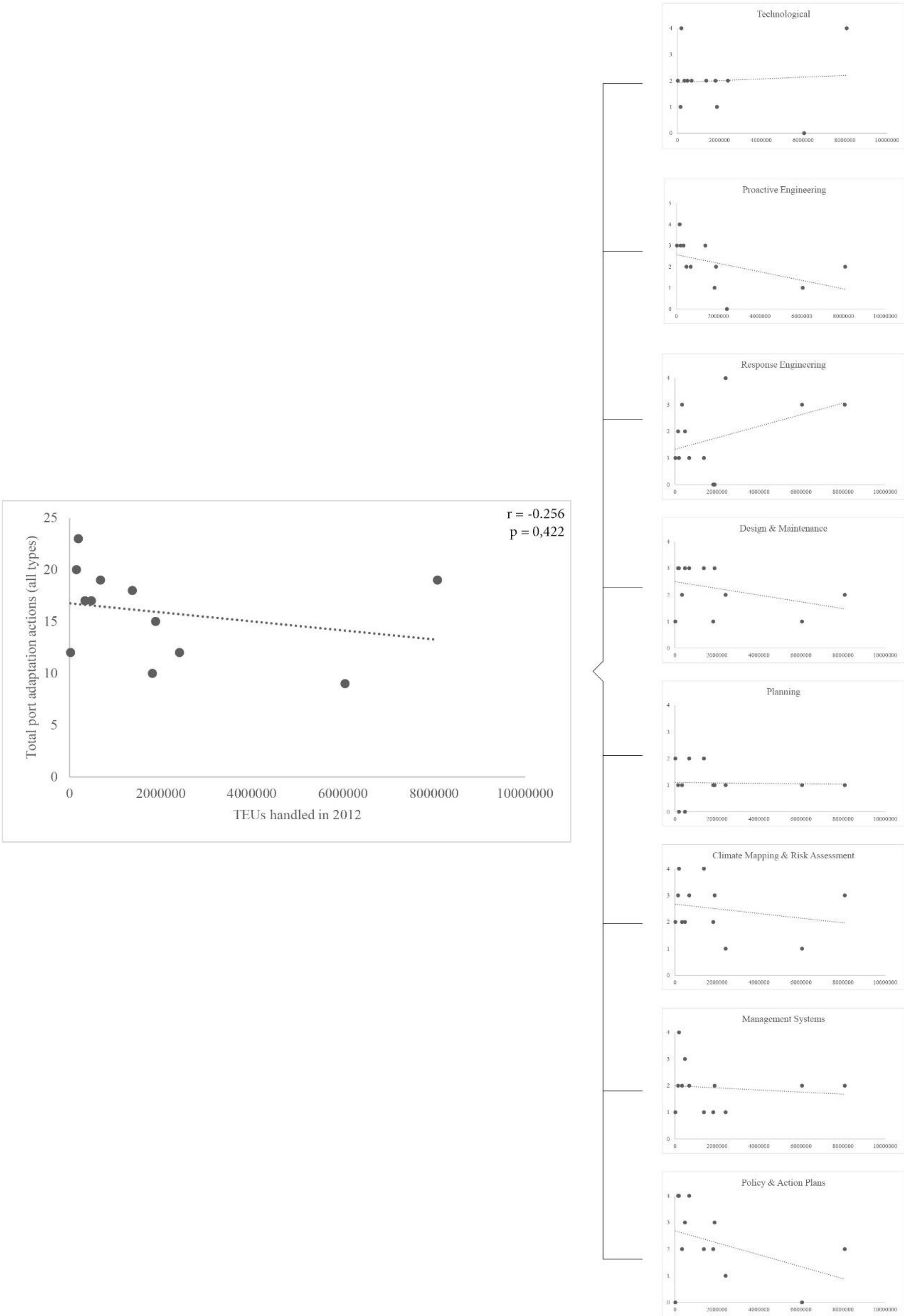
RCI – port actions



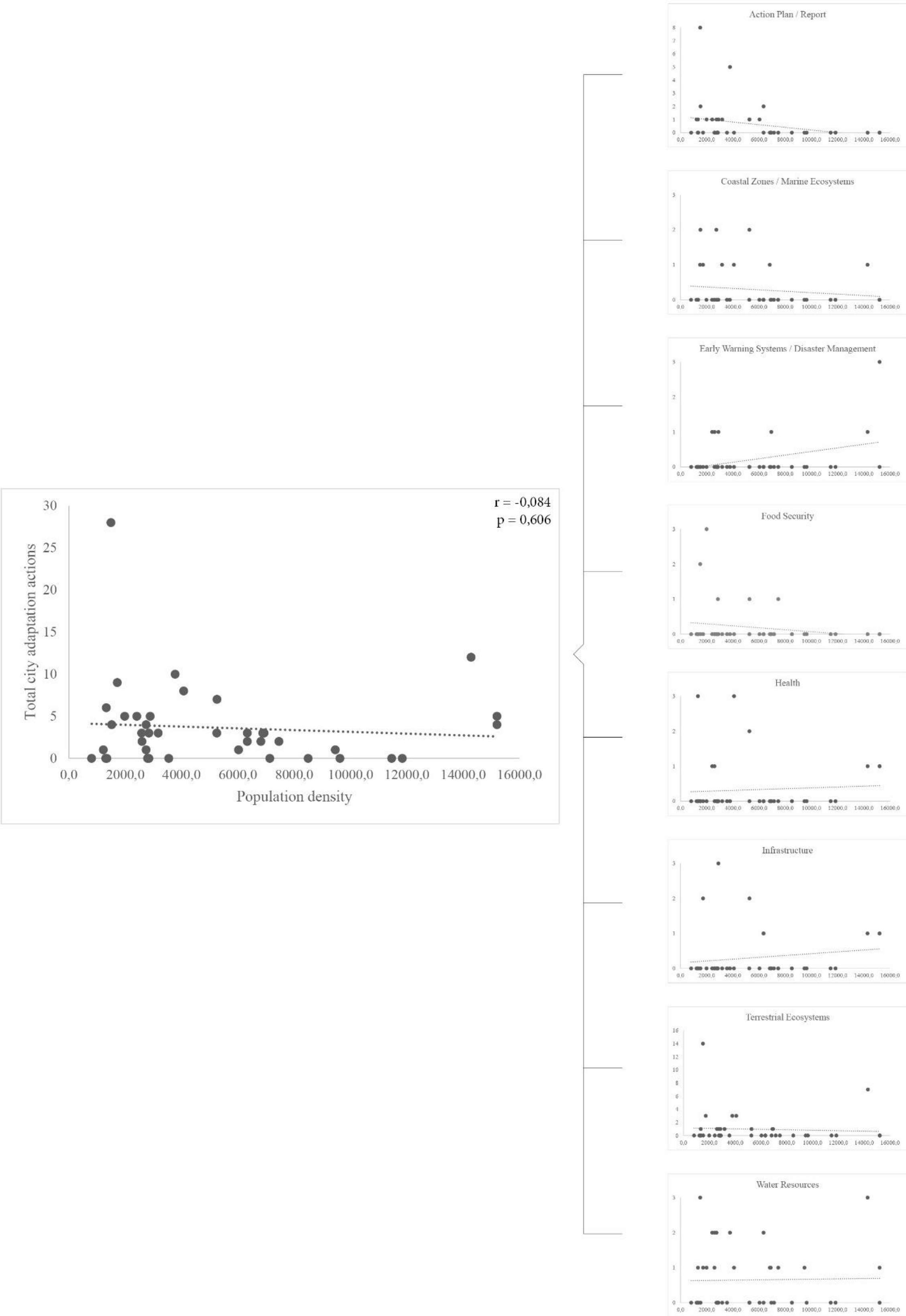
RCI – city actions



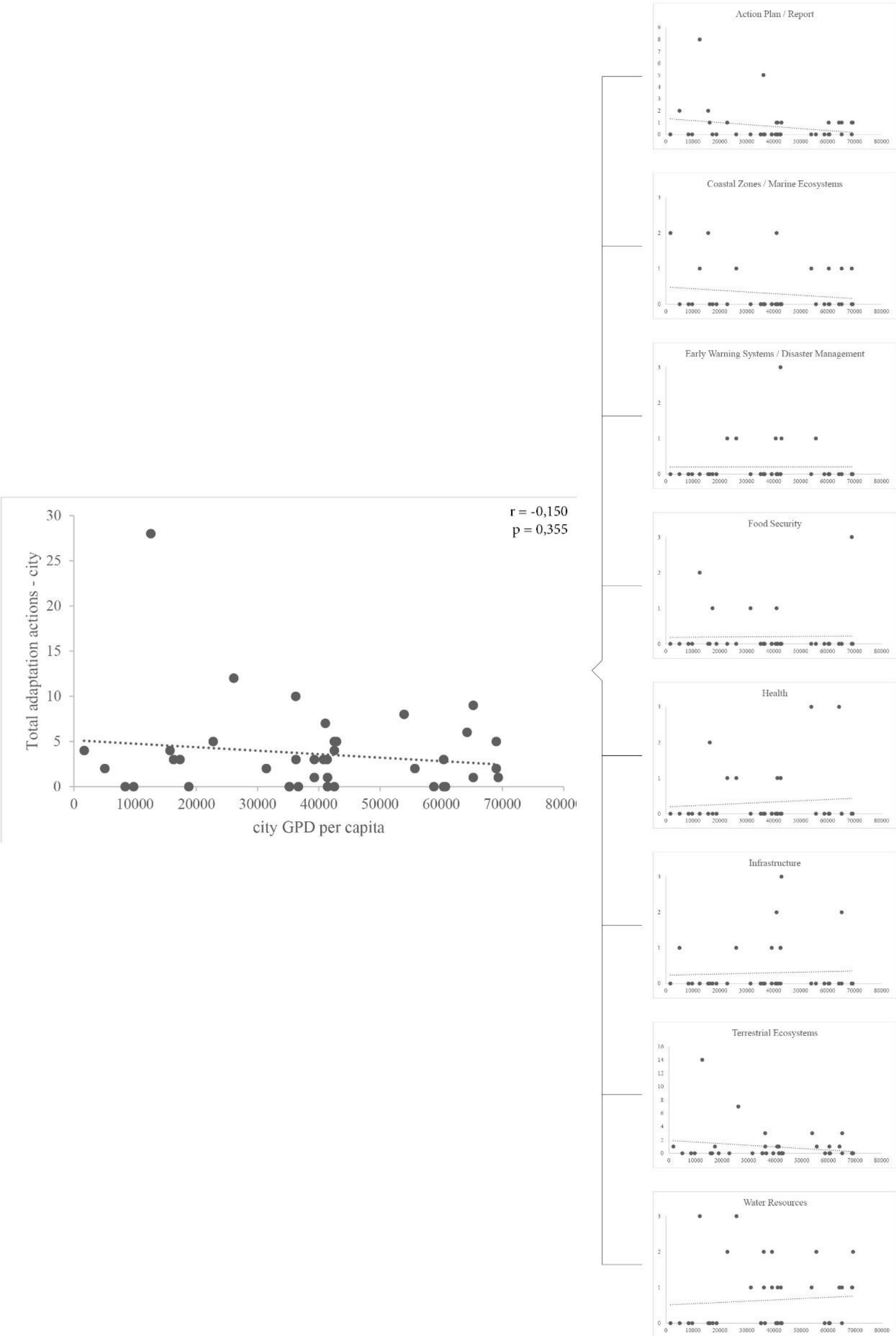
TEUs – port actions



Population density – city actions



City GDP per capita – city actions



Research instruments

Questionnaire used for data collection on ports adaptation actions from Port Authorities

PORT				
PORT AUTHORITY				
MUNICIPALITY				
RESPONDENT NAME				
POSITION IN PORT				
EMAIL				
	PORT AUTHORITY INFORMATION			
		YES	NO	COMMENTS
PORT AUTHORITY TYPE	Public: national port			
	Public: regional port			
	Public: municipal port			
	Private – public			
	Private			
	Landlord port type management			
	Other (please specify)			
	PORT ADAPTATION ACTIONS			
TECHNOLOGICAL	Does the port use technological equipment with durability to climate extremes?			
	Are the storages suitable for wide temperature range?			
	Is there onsite renewable and low emission energy production?			
	Is there automation of logistics procedures?			
PROACTIVE ENGINEERING	Is climate change a consideration for procurement of assets?			
	Can storage facilities that accommodate extreme climate events?			
	Are there dust suppression systems?			
	Is incremental growth of breakwaters being considered?			
RESPONSE ENGINEERING	Are there drainage systems that can cope with projected rain events?			
	Are roadways or rail tracks raised to respond to flooding issues?			
	Are port elevations raised to respond to flooding issues?			
	Are there water retention basins to gather water during flooding?			
DESIGN & MAINTENANCE	Are there alternative routes or transport modal shift in the supply system?			
	Is climate change being considered in future design specifications for buildings and infrastructure?			
	Is there continuous monitoring of infrastructure conditions?			
PLANNING	Is diversification of trade into climate resilient commodities a plan of the port?			
	Is the relocation the port or part of the facilities a consideration?			
	Does land use planning control the use of flood prone areas?			
RISK ASSESSMENT AND MAPPING	Does the port have a weather station measuring climate change variables?			
	Has the port conducted a "Climate change risk assessment"?			

	Is quantification of climate change impacts being done?			
	Is there insurance against risks that the Port Authority is unable to reduce?			
MANAGEMENT SYSTEMS	Is climate change a consideration in the strategies of the management systems/departments of the port			
	Is policy upgraded to include consideration of climate change impacts?			
	Is training on climate change a part of training elements?			
	Is there an emergency preparedness and response system?			
	Does the port cooperate with ports that are at the forefront of climate extremes for knowledge exchange?			
POLICY & ACTION PLANS	Is there a "Port climate change policy / strategy"?			
	Is there a "Port climate adaptation plan"?			
	Are adaptation actions embedded in emergency procedures and risk management?			
	Is there a "Fatigue response plan"?			
	Is there a "Cyclone / Hurricane / Storm response plan"?			
RELATION TO NATIONAL / LOCAL GOVERNMENT	Are port climate adaptation guidelines included in (national) governmental plans?			
	Does the port work in partnership with the city government to plan/design connection to logistics hubs resilient to impacts of climate change in the area?			
	Does Port Authority cooperate with the local (municipal) government on climate change adaptation?			