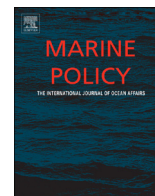




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## Marine Policy

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## Stakeholder awareness of climate adaptation in the commercial seaport sector: A case study from Ireland

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### ARTICLE INFO

#### Article history:

Received 30 December 2015

Received in revised form

21 April 2016

Accepted 24 April 2016

#### Keywords:

Adaptive capacity

Climate adaptation

Maritime industry

Port sector

Stakeholder

Environmental management

### ABSTRACT

Seaports as critical shore-based infrastructure are particularly vulnerable to impacts such as sea level rise and increasing incidents of severe weather events. In excess of ninety percent of global trade by volume is transported by sea. In Ireland, seaports are of strategic importance to the national economy. As an island nation, ninety eight percent of trade by volume comes through its seaports. Climate issues facing Irish ports include increasing storminess, such as the Atlantic storms experienced in the winter of 2014. Ireland provides a particularly valuable case study as the scale of Irish port sizes, analysed in this research, range from 500,000 to 30 million throughput tonnage. This tonnage range, is more typical of port sizes globally, and adds relevance to the study. The specific objectives of this paper are to establish the readiness of the seaport sector in Ireland to build adaptive capacity to respond to climate change and to assess lessons from and for Ireland in the context of international best practice. The research identified a lack of awareness and understanding of climate change amongst the sample population of seventy senior managers (comprising of national regulators and local authorities; commercial port harbour companies; and indigenous and multinational industries located in the port hinterland), as representatives of the maritime sector in Ireland. Evidence of a knowledge gap was identified from in-depth semi-structured interviews conducted over a twelve month period. Many industry stakeholders were actually implementing adaptation measures within their organisational strategies, unaware of the explicit links with climate adaptation.

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### 1. Introduction

The challenge of addressing climate change impacts when viewed through the lens of the port sector is enormous. Sixty percent of the most populated cities throughout the world are categorised as 'port cities' which further emphasises their importance as contributors to both national and global economies [60]. Becker et al [2] suggest that ports, and port based communities will be disproportionately affected by climate change. According to the International Association of Ports and Harbours (IAPH) seaports are vulnerable to changes of all water related

parameters (mean sea level, storm water levels, wind, waves and swell, tidal regime, sedimentation rates, invasive species, water salinity and acidity) [26]. Rapid advances in climate science are seen as the catalyst for sound decision making, and for the development of climate-resilient pathways. As a result of progress in the period between 2005 and 2010, it is now possible for policy makers to make more informed decisions, due to a proliferation of published data, and a continuous development of assessment methods [30,33,35]. Adaptation as a planning and implementation strategy is now central to research on climate change and on climate risk management [47,51].

Evidence from the IPCC [32,35] shows that on a global scale, the ocean is warming (the upper 75 m warmed by 0.11 °C per decade from 1971–2010); and the Greenland and Antarctic ice sheets are losing mass (approximately 275 Gt/year from 1993–2009). Together ocean thermal expansion and glacier mass loss explain about seventy five percent of observed global mean sea level rise.

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In the last century, sea level rose by approximately 0.19 m [34]. This gradual and barely perceptible increase has implications for coastal communities and infrastructure in low lying regions of the world such as deltas and alluvial flood plains; whilst also having implications in the context of sudden and catastrophic coastal flooding events [21,5,58]. The acceleration of sea level rise (SLR) will inevitably have greater implications in the future, especially in coastal regions [35].

The question is, whether port managers, planners and other decision takers are doing enough to consider the vulnerability of port assets in light of the potential impacts of climate change.

Planning for adaptation takes the form of multi-disciplinary teams developing and delivering innovative solutions through adaptive strategies and technologies [41,8,18]. The implementation of adaptive actions involves practical steps to reduce vulnerability including engineering solutions, technical changes to port operations, and planning measures. When referring to the resilience of the port sector or the maritime industry, the authors are referring to a sector's ability to absorb disturbance whilst maintaining its function and structure.

In this context adaptation measures include increasing the resilience of port infrastructure and port operations by evaluating risks of occurrences such as: extreme flooding leading to loss of radar and radio equipment; flooding and erosion of road, railway foundations and storage buildings; toppling of containers in stacking yards; flooding of berth facilities; delays and stoppages in loading and unloading of vessels; and rising insurance premiums due to global losses from weather related events [10,23]. Capital intensive complex projects are predominately engineering options on a large scale basis [40]. They address multiple scenarios from a ports and coastal perspective, and involve the modification and re-installation of sea walls, storm and waste water management systems, flood levees, and the protection of key infrastructure against the effects of storm force winds and flood damage [52].

Ports vary considerably in their operational profiles, the type and extent of cargo handling activities, and in their geographical positions. However synergies may exist and lessons can be transferred between ports where similar challenges are encountered, such as in the case of building climate adaptation capacity. This paper focuses on building adaptive capacity by examining levels of awareness of adaptation to climate change from selected stakeholders across mid-sized ports which make up the port landscape on the Island of Ireland.

The specific purpose of this paper are to establish the readiness of the seaport sector in Ireland to build adaptive capacity to respond to climate change and to assess lessons from and for Ireland in the context of international best practice.

## 2. Methodology

These objectives are addressed by providing insights into current port practice from ports in Europe, Australia and the United States. The research adopts an inductive approach and follows a specific pattern, by analysing secondary data from a broad range of sources (port documentation; journals; publications; academic literature and web based research), and combining it with primary data from semi-structured interviews conducted over a twelve month period, concluding in mid-2014 with seventy stakeholders, representative of port and port hinterland related organisations (see Table 1.); and verification workshop discussions with stakeholders, facilitated by the Department of Transport Tourism and Sport (DTTAS) at their headquarters in July 2015.

A review of ports endorsed by the World Ports Climate Initiative (WPCI) [64] was conducted to establish best practice within this specific industry sector. The relevance of the WPCI to

**Table 1**  
Profile of interview respondents

Analysis Profile of Interview Respondents			
Industry Category		Regulatory Bodies	
Port Industry		Port Authority - Tier 1	10
-Indigenous	12	Port Authority - Tier 2	3
-Multi-national/International	5	Port Authority - Tier 3	1
Port Hinterland Industry (PHI)		Local Authority	6
-Indigenous	10	National Planning & Policy	8
-Multi-national/International	9		
Semi-State Industry	6		
<b>Sub Total</b>	<b>42</b>	<b>Sub Total</b>	<b>28</b>
<b>Total Number of Respondents</b>			<b>70</b>

this study is significant, as it provides a platform for the maritime port sector to highlight the effects of climate change, and to exchange information. The WCPI evolved in 2008 as a result of the IAPH requesting their port environmental committee to consult with regional port organisations, to provide a mechanism to assist ports in dealing with climate change [25]. Through a screening process based on geographic location (with a sample to include a distribution of ports from across the globe); size and tonnage throughput (with a focus on medium to large ports as comparators to the later work on Ireland and because large ports tend to have more sophisticated approaches to innovation); and environmental credentials (ranging from climate policies to port environmental management systems in place), five ports were chosen: - Port of London Authority, Port of Gothenburg, Port of Rotterdam, Port of New York and New Jersey and Gladstone Port, Sydney Port and Port Kembara. These were deemed to be exemplary in providing prime examples of port-based climate adaptation strategies.

Effective adaptation is the ultimate goal of all involved in the commercial seaport sector; however this requires a knowledge base, correct dissemination of information, and a willingness to integrate climate change adaptation into everyday business policy [17]. This study focusses on an assessment of the adaptive capacity of those involved directly and indirectly in the ports and port hinterlands (port companies, local authorities, and those industries that choose to locate in the port environs for strategic or other reasons), with a view to create awareness, contribute to the existing body of knowledge, and enhance the adaptive capacity of the participant stakeholder groupings. Core areas under discussion in this research were 'environmental issues', 'climate change' and 'climate adaptation', as they relate to the maritime industry. For the purpose of this research, 'maritime industry' is categorised as all industries, local authorities, transport and shipping operators, operating within the ports and port hinterlands.

Irish ports were selected following a process that identified and classified ports according to their scale and type. A study of stakeholder awareness of climate adaptation in the Irish commercial port sector was conducted based on in-depth interviews with seventy stakeholders, representative of port and port hinterland related organisations (See Table 1.). The interviews focused primarily on the commercial seaport sector, to ascertain levels of awareness of climate change and climate adaptation.

A stratified sampling methodology was employed in the selection of organisations to provide a balanced representation from both the 'Regulatory' and 'Industry' actors. Regulatory stakeholders comprised of port and local authorities; national planning and policy agencies; and government departments. Industry stakeholders comprised of representatives from port and port hinterland industries (both indigenous and multi-national), and from

semi-state industry. The interviewees selected, were senior managers, policy makers, strategists and business planners with a collective wealth of experience, capable of reflecting the views of both indigenous and multi-national industry, and regulatory authorities. The ports surveyed were chosen as being the primary commercial ports on the island of Ireland (Port of Dublin; Port of Cork; Shannon-Foyne Port; Port of Waterford; Rosslare-Europort; and Port of Galway).

A questionnaire was developed incorporating three core areas of focus: environmental issues; climate change (awareness, impacts and response); and adaptation to climate change (incorporating capacity building). This questionnaire was designed to support the semi-structured interview process. The purpose of the questionnaire was to amass the maximum amount of relevant data over the duration of the interview (90 minutes on average), and the questions were structured to incorporate both a quantitative and qualitative approach to data gathering.

Interview data was analysed using thematic coding, and results presented here represent preliminary findings from an in-depth investigation into the attitudes and behaviours of senior port decision makers towards climate adaptation. The focus is on selected questions around awareness and capacity building. These questions were nested in a larger study dealing with the maritime industry in the context of its resource capabilities, adaptive capacity and responsiveness to climate change. The analysis and presentation of additional results will form part of future work.

### 3. Building adaptive capacity in selected seaports: current international practice

Port management is both strategic and critical in terms of its importance to economies worldwide, and the inclusion of port adaptation practices introduces new challenges to authorities responsible for port management operations [29]. The network of experienced professionals that exist within the port sector is recognised by Smythe [57] who suggests that this (in tandem with effective port governance and a wealth of social capital) needs to be leveraged if the concept of a 'resilient port' is to be identified, and to enable effective long-term planning of climate change adaptation to occur. Building adaptive capacity in the port or any sector is dependent on the resources and capabilities available to undertake actions to manage the impacts and simultaneously exploit potential opportunities of climate change [31].

A selection of international ports engaged in climate adaptation measures are helping to build climate resilience. These include a number of case studies worth considering for comparative purposes against the Irish scenario:-

#### 3.1. Port of London Authority

Under the [59] it is mandatory for major seaports and other infrastructure owners to file reports on their activities relating to climate risk assessment and measures identified to manage such risk [38]. The Port of London Authority (PLA) as the statutory navigation and pilotage authority had its powers and duties extended to cope with the effects of climate change, in so far as it may impact on some of its operational activities and functions. Indicative on the variations in scale and nature of port types and functions, the PLA does not handle cargo, nor does it own land for cargo handling activities. Prior to the implementation of statutory requirements for reporting, the PLA had no baseline data or information concerning the risks of climate change on its operations. The statutory reporting mechanism ensured that the PLA focused on the issue of climate adaptation, resulting in improved understanding of risk and vulnerability to port functions and

departments. The tacit knowledge of port workers was combined with scientific data in an inclusive analytical process. The London Climate Change Adaptation Strategy Gap Analysis (2011) purports that the most important body in London is the Greater London Authority (GLA), with functional executive bodies that include transportation, emergency planning, policing, and development [7]. They (*ibid*) further illustrate how the GLA has also been instrumental in establishing a number of climate related partnerships [London Climate Change Partnerships (LCCP); London Resilience Partnership (LRP)], in an attempt to gain a greater understanding of climate change impacts, and in particular the challenges of adaptation. The stakeholders (including the Port of London Authority) contributing to these functional executive bodies or forums embrace a central theme in the London context of stakeholder involvement, together with collaboration and partnership agreements. Synergies resulting from this partnership and collaborative approach to climate adaptation continues to benefit the PLA, as it is both a contributor and beneficiary of the knowledge transfer process.

#### 3.2. Port of Gothenburg

The Port of Gothenburg is a signatory to the climate strategy of West Sweden (2009) whose overall goal is to be independent from fossil free energy by 2030 [20]. The Port of Gothenburg purports to be recognised as a world leader in on-shore power supply for shipping and for cleaner air as a result of its programmes on fuel quality, including its prominent role in related projects in the World Port Climate Initiative [65]. Published sustainability reports by Gothenburg Port Authority [48,49] describe the implementation of mitigation measures across the port such as on-shore power supply connections (cold ironing); vapour recovery system; ECO-driving (rail shuttle within port hinterland); and financial support for environmental shipping companies selecting cleaner fuels in the fairways. Of note is the absence of any mention of climate change adaptation in the sustainability reports. Stringent environmental demands; geographic location and distance from major growth regions have been the drivers for Gothenburg in having to provide effective and efficient port and land logistics systems. Consequently, in attempting to maintain its status as a leading freight hub, the Port of Gothenburg views collaboration with stakeholders [owners; customers; employees; society and general community; suppliers; public agencies; terminal operators; and port community] as the key to lasting success [50].

#### 3.3. Port of Rotterdam

The geographic, deltaic context of the Port of Rotterdam places it in a location that is highly vulnerable to flood and sea level rise. This vulnerability is exacerbated by the presence and activities of a dense, exposed, growing population. The importance of knowledge development is acknowledged by key stakeholder groupings [City of Rotterdam; Port of Rotterdam; Rotterdam employers' organisation (Deltalinqs); Environmental Protection Agency Rijnmond (DCMR)] as being instrumental in developing Rotterdam's adaptation strategy [36,63]. Rotterdam Climate Initiative [53] reveals how the Port of Rotterdam Authority has fostered collaborative agreements with wider stakeholder groupings [municipal services; government departments such as the water boards and Rijkswaterstaat; the general public; private commercial organisations including housing corporations; project developers; and utility providers] to develop the Rotterdam Climate Proof Programme.

According to the Rotterdam Climate Proof Adaptation Programme [54], the focus is on deriving and implementing strategies for climate proofing, rather than prediction, with the aim of making Rotterdam 100% climate proof by 2025. With a

globally recognised track record in flood risk management in the Netherlands, the adaptation strategy is premised on a flood risk ratio at 1:1,000 years [62]. Climate change adaptation strategies, including integrated port design and refurbishment works, are being incorporated into port spatial planning in the Netherlands [63]. Rotterdam's commitment to partnership, collaboration, and knowledge transfer is further evident from their strategic approach to Memoranda of Understanding, whereby knowledge is exchanged with foreign partners (government bodies; governmental agencies and port authorities) with the objective of enhancing and optimising performance, and future development of ports [19].

### 3.4. Port of New York and New Jersey

The poor ranking of US ports in an Organisation for Economic Co-operation and Development (OECD) study [43], analysing the vulnerability of the world's largest ports to extreme weather events (storm surges, flooding) prompted the publication of a white paper on 'planning for climate change impacts at US ports' [61]. The Port Authority of New York and New Jersey adopted a sustainability policy with specific emphasis on minimising risk to its facilities as a consequence of climate change, as well as highlighting their intentions to work with regional stakeholders in an attempt to alleviate such risk.

The Climate Change Adaptation Task Force was set up with two specific goals: to determine which facets of their infrastructure were at risk due to climate change, and to develop a co-ordinated adaptation strategy to protect the respective infrastructure [39]. The Port Authority assigned responsibility of various facets (energy; policy; transportation; communication; water and waste) to various working groups with a central premise of a coordinated and collaborative approach to produce a strategy that would address potential vulnerabilities.

This collaborative approach was also recognised by The Transportation Research Board (TRB) as being core to developing 20 to 30 year outlooks with stakeholder bodies (environmental protection; national resource management; and agencies responsible for land usage). The Port Authority conducted an analysis of potential vulnerabilities and challenges by 2020, 2050 and 2080 respectively, and set about structuring their design and maintenance programmes accordingly. The unprecedented impact of Hurricane Sandy has shown that despite having processes in place for adaptation planning, the outcomes in terms of levels of preparedness for extreme events can still be inadequate.

In addressing the impacts of Hurricane Sandy on the ports of New York and New Jersey, Smythe [57] examines how such occurrences might inform future planning in relation to threats from climate related events. The vulnerability of the port of New York and New Jersey to extreme storm surges has become an issue, as the odds of such occurrences as a consequence of climate change are on the increase [22]. The network of experienced professionals from various stakeholder groupings, that exist within the port sector is recognised by Smythe [57] who suggests that this (in tandem with effective port governance and a wealth of social capital), need to be leveraged if the concept of a 'resilient port' is to be identified, and to enable effective long-term planning of climate change adaptation to occur.

### 3.5. Gladstone Port, Sydney Port and Port Kembla, Australia

Concern that climate change will adversely affect the otherwise successful operations of the Australian port sector, led the National Climate Change Adaptation Research Facility (NCCARF) to commission a project 'Enhancing the resilience of seaports to a changing climate' [37]. This collaborative approach to assess the effects

of climate change on seaports and their environs, and to identify adaptation options, was structured on the basis of risk management [55]. The multi-disciplinary climate resilience project in collaboration with key stakeholders [such as: Ports Australia; Transport & Logistics Industry Skills Council; Shipping Australia Limited; and the Maritime Union of Australia], identified important vulnerabilities: seaward-side operations and supply chain disruptions as being most affected by climate change [37]. Annual reporting by 'Infrastructure Australia' to the Council of Australian Governments explicitly includes climate change adaptation, where in this context contingencies are provided for the assessment of risk to infrastructure from climate change; the management of such risk; and the need to alter the design or location of infrastructure to reduce future risk [27,28].

The importance of Australian ports as links in global supply chains is emphasised by Ng et al., [42] who raised the issue of dependency of related sectors such as manufacturing and transportation on port operations. The significance of ports is further enhanced by the level of dependency of stakeholders in the logistics and transport sector, where it is necessary for collaboration and coherence to exist to enable implementation of effective adaptation strategies.

## 4. Review of Irish ports

### 4.1. Irish seaport characteristics

Typically, the ports in Ireland are seaports in natural, deep-water sheltered harbours, co-located with centres of population. Through-flow traffic at Irish seaports in 2011 consisted of over 12,000 vessels which carried approximately 45M tonnes of cargo through 19 different ports [15]. As an island nation, ninety eight percent of trade by volume comes through its seaports [9]. The largest port is the Port of Dublin on the Eastern Seaboard. Governance of the port sector is broadly similar to that existing elsewhere in Europe, with a mix of private sector involvement, in tandem with ports controlled by local authorities. The size, location and strategic importance of various ports differs widely depending on a range of factors; proximity to commercial and industrial centres; links to internal infrastructure; and the concentration of centres of population throughout the island of Ireland. In 2013, the National Ports Policy was introduced to address the diversity as it exists throughout the port sector, with the long-term aim of consolidating resources to allow for an effective and competitive maritime transport sector [15]. This policy categorised the ports into three groups:-

- **Ports of National Significance - Tier 1**, responsible for 15–20% of the overall Irish throughput tonnage of which there are three: Port of Dublin, Port of Cork and Shannon-Foynes Port.
- **Ports of National Significance - Tier 2**, responsible for at least 2.5% of tonnage of which there are two: Port of Waterford and Rosslare-Europort.
- **Ports of Regional Significance**, encompassing the remainder of the Irish commercial ports namely, Galway Port, Drogheda, Dun Laoghaire, New Ross and Wicklow.

This study focused on Tier 1 and Tier 2 ports, including the largest of the regional ports, which was Galway Port. Belfast Port is another significant port on the island, but it was not included for the purpose of this research, as it falls within a separate jurisdiction (Fig. 1).

Climate conditions differ between the east and the west coasts of Ireland. Ports on the east and south coast are sheltered relative to the exposed and extreme Atlantic waves and conditions that influence maritime traffic and port operations on the western seaboard. The increased occurrence of severe weather events poses significant

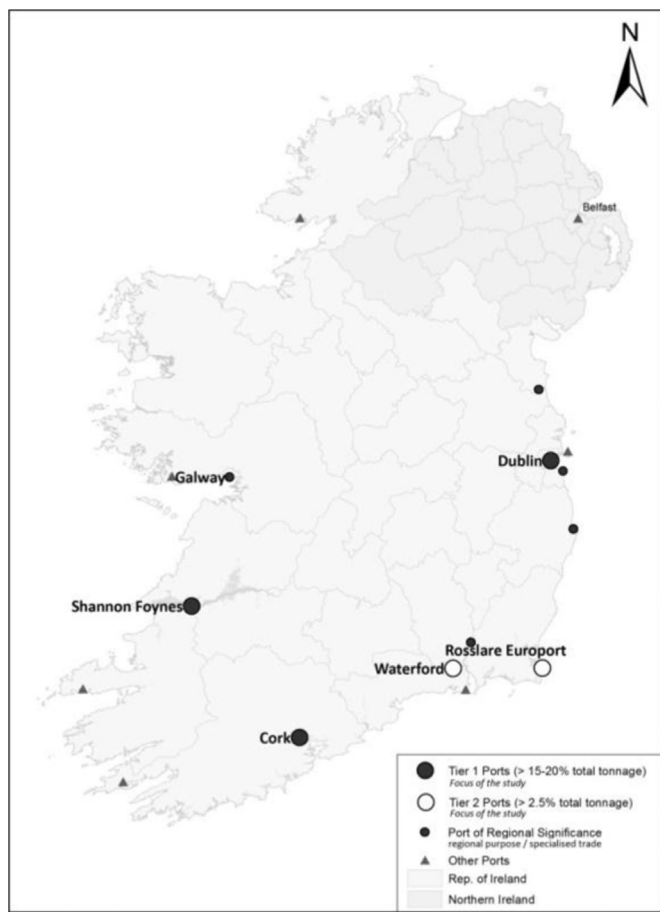


Fig. 1. Ireland's Main Ports & Harbours. Source: (Author).

challenges to Irish port operations. Wind in particular has a substantial effect on the berthing of shipping, and the subsequent loading and unloading of cargo. Specific types of cargo are susceptible to damage by precipitation resulting in ships having to remain for longer periods in port to facilitate the safe unloading of cargo. A sizable percentage of the physical expansion of ports has taken place on reclaimed land within the port environs. This requires adaptation measures to be put in place to safeguard infrastructure, to prevent flooding and coastal erosion, as a consequence of more frequent storminess with respect to adaptation [16].

The National Climate Change Adaptation Framework was developed to address the issue of climate change, by advancing the knowledge base and providing future structures and processes to enable capacity building across all sectors of the economy [11]. It is envisaged in the National Climate Change Adaptation Framework that analysis of the response to climate change on a sectorial and local basis, will be at an advanced stage by 2016. The Environmental Protection Agency (EPA) has been given the lead role in assembling evidence in developing tools to enable organisations across all sectors to understand, address and adapt to climate change impacts. This is likely to provide a catalyst to action in the Irish seaport sector, which is currently not being catered for in terms of assessment of vulnerabilities and adaptive capacity with respect to climate change. Seaports are of strategic importance to the national economy, and it must be assumed that they form part of critical infrastructure. However, adaptation to climate change is a relatively new policy area, and it remains unclear as to what will be categorised as critical infrastructure into the future [56]. Shine and Desmond (*ibid*) further contend that there is no best practice

to reference, as climate change adaptation is an emerging area of work, where all actors are pursuing a learning by doing process. The National Ports Policy does not include any mention of contingencies against possible future vulnerabilities of the ports in Ireland as a consequence of climate change [15].

## 5. Preliminary findings: Stakeholder awareness and adaptive capacity in the commercial seaport sector in Ireland

### 5.1. Pathways towards capacity building for environmental management

The past four decades of environmental management have seen great changes, from the nascent days of early environmental movements, to contemporary, policy tools that span the spectrum from promotion of compliance to enforcement of regulation. In general many ports around the world have responded to the changes that have come about as a result of increasing environmental legislation. In many cases ports have embraced embedded tools such as environmental management systems to improve operations, public perception, and their financial bottom line. In this study, the interviewees were asked about the importance of environmental management to port operations to identify the motivating factors for the delivery of good environmental practice within Irish ports. The aim of the questioning was to establish if there are lessons to be learned from the way that ports have responded to the challenge of better environmental management.

General discussion topics covered included Environmental Management Systems (EMS), both port specific (Port Environmental Review System PERS), and generic management systems (International Standards Organisation ISO14001). Vulnerability of the port sector, vulnerability of industry and risk management was also discussed, as was resource capabilities, and resilience of the maritime industry. Specific focus was given to the interviewees understanding of climate adaptation, and discussion took place to determine individual organisation's adaptive capacity and their commitment to adaptation strategies.

Almost all the interviewees considered environmental management of the port sector to be 'very important', with the remaining interviewees identifying with 'somewhat important'. The majority of participants referenced their corporate strategies as key enablers for a proactive approach to environmental management. Regulatory stakeholders tended to identify with corporate social responsibility (CSR), and the desire for a clean, green image, as important for the environmental management in ports. One port authority participant emphasised the "key objective of our thirty year port master plan is environmental management".

Under one-third of interviewees identified with the need for 'protection of the environment' as the main driver of environmental management in ports, with equal representation from regulatory and industry stakeholders. Participants cited stakeholder responsibility, environmental awareness, a sustainable approach to business, and the protection of 'our common future' as important drivers for environmental protection. One industry participant reflected on organisational culture and attitude towards environmental protection, stating "our industry is non-indigenous and has a very visible footprint along the shoreline (industrial buildings, chimney stacks and steam plumes), resulting in a critical need for environmental awareness throughout the organisation". The regulatory stakeholders strongly supported protecting the environment. This was expressed by a port authority participant as "ports impose themselves on the environment and need to be sustained". Another local authority participant highlighted the "critical inter-relationship to the city, residential and recreational uses of the bay and working operation of the port itself".

A further one-third of the interviewees (equal representation from regulatory and industry stakeholders), identified with 'adherence to policy and regulation' as a key driver of environmental management in ports, with reference to government policy, environmental regulation, international maritime regulation (MARPOL- The International Convention for the Prevention of Pollution from Ships), and compliance with landlord port environmental management systems. The increasing pressures and constraints on businesses with regard to compliance in the port sector emerged as a key issue.

### 5.2. Awareness and acceptance of climate change in the Irish commercial seaport sector

A good appreciation of the value of environmental management among the interviewees was matched by a strong response on a line of questioning to gauge levels of acceptance of climate change. Overall, eighty three percent of respondents felt that climate is changing. Many supported this viewpoint by citing personal experiences of extreme weather events such as increased storm activity and flooding due to intensity of rainfall. Levels of awareness of climate change among port industrialists and regulators tended to be varied depending on the sources of influence and information open to the interviewee. As well as personal experiences, interviewees tended to have developed their knowledge of climate change issues from their educational backgrounds (e.g. as geographers or environmental scientists) or from media sources such as television documentaries or newspaper articles.

Perceptions of the impacts of climate change from the perspective of those port managers in agreement with the science of the IPCC tended to focus on issues around the increased risk of flooding and stormy weather on the viability of year-round port operations. These issues were identified equally by both regulatory bodies and industry representatives surveyed. Vulnerability of transport and vulnerability of supply chains were two other issues that emerged strongly in the interviews. In contrast temperature extremes were considered a low priority for most of this cohort apart from utility and some heavy industry participants, who were considering measures such as investing in double skin silos to maintain moderate temperature levels and advance planning to future proof critical plant and machinery.

Ironically one in three of those respondents who agreed that climate is changing, went on to suggest that there are no obvious impacts of climate change, scientific evidence is poor, and what we are witnessing is part of a cyclical, gradual change phenomenon. The remaining respondents seventeen percent were of the view that climate is not changing. A typical viewpoint was that "*weather patterns are changing, not sure if the climate is changing*".

### 5.3. Awareness and understanding of adaptation to climate change

There was a general lack of understanding of adaptation as an explicit term or process for dealing with climate change in the port sector in Ireland. Despite this, the interviewees were intuitive about the impact of weather related issues on business planning. Given the severe weather events in Ireland in recent years, all stakeholders were aware from first-hand experience of the impacts of weather related issues on the functioning of their organisations, and the resultant effect on the economy.

Discussion with interviewees who expressed having some understanding of climate adaptation revealed a flawed interpretation of the term, necessitating an adjustment to the original findings in relation to the 'no' category, to a true adjusted value of seventy one percent. Levels of understanding within the representatives of the regulatory bodies were at fifty percent compared with a mere seven percent in the representatives from industry. This illustrated

a large knowledge-gap across between industrialists and regulators. Those classified as having an understanding of climate change adaptation provided insights into their thinking on the subject, such as:- "*learning from our past and adapting for the future with the help of scenario planning tools*"; "*responding to the inevitable consequences of climate change by building resilience into our business models, modifying our supply chains, and adapting our resources*".

Fifty eight percent of individuals surveyed indicated they had been involved in managing the impacts of extreme weather events. Of these ten percent were actively pursuing the implementation of adaptation measures, such as new power plants built to cater for extra winds and rainfall; raised platforms; and modifications to structural fittings, interceptors and drainage systems.

### 5.4. Building adaptive capacity in the Irish commercial seaport sector

There was generally a positive response and openness towards capacity building within the maritime port sector. Sixty four of the interviewees displayed a willingness to participate and contribute to developing an understanding of how to build adaptive capacity within their own organisations, in both industry and regulatory bodies. Only six percent of the sixty four would await national policy and regulations in advance of any developing proactive actions on their part. The authors observed a reluctance of a minor percentage of those interviewees (tenants of landlord ports), to undertake a proactive approach to capacity building as they believed the burden of responsibility for such actions rests with the port landlords.

Key issues to be addressed through capacity building with port managers were noted as:-

- The need for training and skills to assess risk and vulnerability within port management organisations
- The need to broaden engagement with the issue of climate change by harnessing opportunities for continuous personal development
- The need to introduce scenario planning and modelling capabilities to deal with climate risk and uncertainties
- The need to learn from best practice and to facilitate knowledge transfer from other ports or other economic sectors
- The need for access to better scientific data and information on long-term trends in weather and climate
- The need to engage with other stakeholders including the general public
- The need to include climate change adaptation in strategic business planning

Bearing in mind a limited understanding and awareness of climate adaptation, eighty percent of the interviewees considered that their organisations had sufficient or surplus human capital and financial resources to deal with capacity building for climate change adaptation into the future. It was broadly acknowledged that internal capacity building should be matched with a national framework policy with mandatory participation, in tandem with grants to encourage organisational involvement in climate change adaptation.

## 6. Discussion

In seeking case studies to review to provide context for the research into seaports in Ireland, it became apparent that there is limited information on adaptation to climate change in small to

medium sized ports in general. A small number of global mega-ports are leading the way. However progress in general is slow as the need to build adaptive capacity as well as implementing mitigation is a relatively recent area of focus.

Nevertheless, as seaports are particularly vulnerable to the impacts of climate change, it is important that progress continues to be made. Lessons can be learned from the WPCI's [64,65] initiatives relating to raising awareness, and providing a platform for the maritime sector to enable information sharing; and from port specific individual case studies where a proactive approach to climate adaptation was evident. This approach supports the findings of the analysis of the European and global ports identified as meeting the research criteria of this study. Lessons learned from these ports, included the importance of stakeholder engagement; and a need for collaboration between individual ports irrespective of their competitive position. The proactive approach of ports to developing adaptation strategies, and individual climate goals was encouraging; and the long-term benefit of mandatory reporting was revealed to be potentially significant from a legislative and regulatory standpoint. The mission of the WPCI remains steadfast, and the number of member ports, and associate member ports continues to grow globally.

It is clear from the review of international practice that there is also variability in the drivers that trigger a response towards building adaptive capacity. Drivers in the case studies ranged from legislative drivers (Port of London Authority), drivers concerned with atmospheric quality (Port of Gothenburg), the need to deal with extreme vulnerability (as in the case of low-lying Rotterdam), responding to negative rankings (Port of New York and New Jersey), or impact on operations (Australian ports). There were no examples of a proactive approach to climate adaptation as a result of commercial potential arising from more effective or efficient port operations. It seems as if the link between building capacity to adapt to climate change is seldom, if ever, grounded on an opportunity to make long term savings. This could reflect the short term nature of business planning in ports, which seeks to adapt to global trends in the distribution of trade on a quarterly or annual basis.

Disruptions to supply-chain for an island nation such as Ireland need to be highlighted, to enable ports and businesses to compete globally. Critical links between safety, health and the environment, are increasingly visible to the stakeholders following more frequent and extreme storm events and resultant flooding. This helps to reinforce the climate change message. As a consequence of the severe weather events in Ireland over the past five years, including most recently winter of 2015, flood defence management measures are currently being introduced across the country. The ports within the study group are particularly vulnerable to the volatility of powerful Atlantic storms, however, flooding is experienced in all of the Tier 1 ports, from the catchment or the coast, depending on environmental scenarios. Flooding is likely to be the primary driver for port orientated action in response to climate change in Ireland. The absence of the use of the term 'climate adaptation measures' by those responsible for various hard engineering initiatives such as proposed in the Catchment Flood Risk Assessment and Management (C-FRAM) programme, highlights the need for an overarching policy and understanding of the wider consequences of climate change [46].

Not only is every seaport different, with their range of functions and variability in cargo, but each port faces localised climate risks from a combination of climate related hazards and vulnerability of different infrastructures. While there is no single driver that can be identified as a trigger for action, there is equally no generic solution for ports.

Emerging from current practice in the case study ports is the importance of overarching policy frameworks; and the need for

stakeholder engagement in the formulation and implementation of strategy and policy. Action for adaptation in the international seaports was consistently undertaken as a result of nested policy environments. In each case, port authorities had engaged with the development of adaptation strategies as a result of policy or legislative drivers. This suggests that port managers have yet to be convinced of the imperative of developing bottom-up approaches to climate adaptation, possibly because of a gap in understanding or knowledge of the cost of action versus inaction, or because of the mismatch in timelines between port, and adaptation planning and management.

Rather than a commercial and financial focus, the actions of the Port of London Authority are driven by a need for compliance with the [59]. The adaptive actions of other ports are linked to national or regional targets in programmes such as the Climate Strategy of West Sweden 2009 [3] or the Rotterdam Climate Change Strategy 2013 [53]. Not only is the policy environment a catalyst for action, it can also be seen from the case studies that the policy frameworks ensure that adaptation strategies for ports are not delivered in an isolated or singular fashion. Rather they can become part of a nested architecture that embeds port strategy into greater urban, regional or nationally driven initiatives. In the Irish case, the slow rate of progress in relation to the Climate Action and Low Carbon Development Bill (2014; 2015) [12,13] means that the knock on effect of overarching policy and legislation is yet to be felt, including in the Port sector.

The steps involved in building adaptive capacity in ports are linked to access to scientific data and information, coupled with engagement across multiple stakeholders to assess risk and vulnerability. Stakeholder involvement stands out as being central to the adoption of climate change adaptation measures in ports, as ports provide a unique opportunity to tap into the tacit knowledge of port workers, as seen in the Port of London Authority, which is important when dealing with local environmental specificity. The success of the Australian seaport resilience project was supported by a multi-disciplinary engagement with a range of different stakeholders' representative of the scientific community, regulatory and port authorities, and hinterland industry practitioners. Engagement with stakeholders is increasingly part of the *modus operandi* of well-developed ports. Planning for new port infrastructure often provides for consultation with relevant stakeholder groups, but significant capacity has been built, as demonstrated through the Irish case, through capacity built by ports in complying with Port Environmental Management Systems. The 'greening' of ports has helped to transform the way ports engage with communities, and as such, this inherent capability provides a stepping stone for building adaptive capacity as the challenge of climate change becomes an increasingly pervasive issue.

Of particular note in both the UK and Australian context was the mandatory reporting by owners of major seaports and other critical infrastructure on their activities relating to climate risk assessment, and measures identified to manage such risk. Such reporting measures, done well, with good transparency can become tools for communicating and for building confidence with regulators and citizens alike.

The approach to the development and implementation of an overarching policy framework for climate change in Ireland can be described as piecemeal and slow. This is not dissimilar to the national approach to coastal zone management [4]. The last National Climate Change Strategy 2007–2012 [14] action plan expired in 2012; there is no whole of government policy direction on how to meet Ireland's fast approaching 2020 targets; and sectorial plans are being progressed in the absence of progress on the Climate Action and Low Carbon Development Bill (2014;2015) [12,13]. The need to integrate adaptation planning and strategies into programmes and policies of government, as well as stakeholders of

organisations and institutions across all sectors was highlighted by the international case studies. This is an issue for Ireland that will have an impact on progress across the board, including in the Irish seaport sector.

The research shows that the Irish seaport sector is well-tuned to the importance of environmental management, and that port managers are motivated by the importance of good environmental husbandry to business. Over many years the ports sector has come to recognise that environmental management is a fundamental component of good business. Over the last four decades the environmental movement has been influenced by a blend of public awareness, regulation, stakeholder engagement, corporate social responsibility and compliance via new environmental management systems. These influences transcend modern port practice. The question is whether the pathway towards building capacity for environmental management in ports can provide a stepping stone for understanding how ports might respond to the issue of climate change. Discussions with those responsible for providing major infrastructural projects in recent years, reveal that many industry stakeholders were actually implementing adaptation measures (new power plants are built to cater for extra winds and rainfall; raised platforms as part of new infrastructure; interceptors incorporated in drainage systems; fixtures and fittings to an increased structural rating), within their organisational strategies but were not aware of the explicit links with climate adaptation

Central to this discussion is awareness and understanding of climate change and the need for appropriate action in the form of both mitigation and adaptation. It is clear from the research that there is cause for concern about the level of awareness among senior port stakeholders of the importance of adaptation to climate change in particular. There has been little or no proactivity among Irish ports to date. One exception is the Port of Cork, who participated as partners in the Coastal Research and Policy Integration (COREPOINT) programme [1,44,45] which laid the foundations for identifying coastal specific vulnerabilities to climate change and related issues, and contributed to Climate Adaptation Strategy for Cork harbour [6,24].

There appears to be a strong appetite to engage in capacity building to address this issue, and numerous resources can be brought to bear on such an effort. Of note are the increasing levels of sophistication in the monitoring of environmental parameters around ports, and the opportunity to incorporate existing data into future climate models. Ports are complex systems, including environmental, economic and social parameters. As such, processes need to be developed that can deal with all of these interactions to deliver coordinated risk assessment in tandem with a programme of communication and awareness to educate stakeholders on adaptation processes in the seaport sector.

## 7. Conclusion

Seaports represent critical coastal infrastructure and they are the frontline for global trade and development. Despite this, little work has been done on assessing vulnerability, resilience and building adaptive capacity to climate change. Some ports stand-out internationally, such as those engaged on the World Ports Climate Initiative, and lessons can be learned on how such ports are going about the business of building adaptive capacity. There is no silver bullet, and some ports remain vulnerable, despite demonstrating good practice in policy and practice, as demonstrated by the impact of Hurricane Sandy on the Port of New York and New Jersey.

Drivers for climate action among ports vary from dealing with risk to reputation, port operations and litigation. The need for

overarching policy frameworks emerges as an important prerequisite for port managers to initiate stakeholder engagement to build adaptive capacity. Ports can leverage their increasingly sophisticated approach to involving stakeholders in port planning and management decisions, especially with regards to large scale port infrastructure projects.

It is apparent from this research that a considerable amount of work needs to be done with the seaports sector alone, in order to facilitate a combination of top-down and bottom-up approaches to building adaptive capacity for dealing with climate change. Ireland is not atypical. At the national level Irish policy makers are slowly implementing a range of instruments to comply with European directives and international protocols. There is need to move towards sector specific guidance and regulation to deal with the impacts from diverse sectors important to the Irish economy such as agri-food, ICT and seaports.

A starting point has to be, to address the gap in knowledge and awareness of climate adaptation across senior port managers that is evident in the case analysis from this research. While acknowledging there is substantial work done by port professionals associated with WPCI, where topics related to Climate Change are presented at conferences, directly to its members, this is only the tip of the iceberg. The institutional culture needs to be taken into consideration. Ports are motivated by profit as the bottom line. This leads to conflict between short-term planning and long-term horizons, however this is no different to many other economic sectors. Importantly, the study revealed an appetite for increasing understanding in capacity building from port managers, industrialists and regulators. This willingness can be leveraged, alongside the case history of implementing environmental management systems in the port sector. Capacity building needs to encompass the full spectrum from technological solutions to behavioural and policy approaches to climate adaptation.

## Acknowledgements

The authors acknowledge the funding support of those organisations that funded the study: Cork Institute of Technology (CIT); and Marine and Renewable Energy Ireland (MaREI) Centre, University College Cork (UCC). We also thank the reviewers of this paper, interview partners, workshop participants and collaborators in the on-going research. The paper is part of a broader study on Maritime Industry in the context of its resource capabilities, adaptive capacity and responsiveness to climate change.

## References

- [1] R. Ballinger, V. Cummins, A., M. O'Hagan, M. Philippe., *The point of COREPOINT: improving capacity for integrated coastal zone management in North West Europe*, Cork:Corepoint, 2008 2008.
- [2] A. Becker, S. Inoue, M. Fischer, B. Schwegler, *Climate change impacts on international seaports: Knowledge, perceptions, and planning efforts among port administrators*, *Climatic Change* 110 (1) (2012) 5–29.
- [3] *Climate Strategy for Western Sweden (Västra Götaland)*. (2009). Smart energy: How we can create sustainable Development together.
- [4] J.A.G. Cooper, V. Cummins, *Coastal research and policy integration in North West Europe - The COREPOINT project*, *Marine Policy* Vol 33 (2009) 869–870.
- [5] A. Cooper, C. Lemckert, *Extreme sea-level rise and adaptation options for coastal resort cities: A qualitative assessment from the Gold Coast, Australia*, *Ocean Coast. Manag.* 64 (2012) 1–14.
- [6] *Cork Harbour Integrated Management Strategy*, 2008. Downloadable at: [http://www.corkharbour.ie/pages/cork\\_harbour\\_strategy.pdf](http://www.corkharbour.ie/pages/cork_harbour_strategy.pdf).
- [7] Davoudi, S., Mehmood, A., Brooks, L. (2011). *The London Climate Change Adaptation Strategy: gap analysis*. [Project Report]. Electronic Working Paper Series, vol. 44. Global Urban Research Unit. Available at: <http://www.ncl.ac.uk/guru/documents/EWP44.pdf>.
- [8] R. Dawson, *Re-engineering cities: a framework for adaptation to global change*, *Philosophical Trans. R. Soc. Ser. A* 365 (1861) (2007) 3085–3309.

- [9] Department of Agriculture, Food and the Marine. (2012). HARNESING OUR OCEAN WEALTH: An Integrated Marine Plan for Ireland- Roadmap, New Ways, New Approaches, New Thinking.
- [10] Department for Environment, Food & Rural Affairs (DEFRA), (2012). Climate Change Risk Assessment. [pdf] London: Department for Environment, Food & Rural Affairs. Available at: <http://www.defra.gov.uk/publications/files/pb13698-climate-risk-assessment.pdf>.
- [11] Department of the Environment, Community & Local Government. (2012). National Climate Change Adaptation Framework: Building resilience to Climate Change.
- [12] Department of the Environment, Community and Local Government, (2014). Climate Action and Low Carbon Development Bill, 2014. Downloadable from: <http://www.environ.ie/en/Environment/Atmosphere/ClimateChange/>.
- [13] Department of the Environment, Community and Local Government, (2015). Climate Action and Low Carbon Development Bill, 2015. Downloadable from: <http://www.environ.ie/en/Environment/Atmosphere/ClimateChange/>.
- [14] Department of Environment, Heritage and Local Government. (2007). National Climate Change Strategy 2007-2012. pp. 7-37.
- [15] Department of Transport, Tourism and Sport. (2013). National Ports Policy 2013. Downloadable at: <http://www.dttas.ie/sites/default/files/press-releases/national-ports-policy-2013-web.pdf>.
- [16] M. Desmond, P. O'Brien, F. McGovern, EPA Climate Change Research Programme 2007-2013, A Summary of the State of Knowledge on Climate Change Impacts for Ireland, EPA, Dublin, 2009.
- [17] M. Desmond, Shine, EPA Climate Change Research Programme 2007-2013, National Adaptive Capacity Assessment, EPA, Dublin, 2012.
- [18] R.J. Devoy, Sea-Level Rise: Causes, Impacts, and Scenarios for Change -Chapter 8, Coast. Marine Hazards, Risks Disasters 2015 (2014) 197-241.
- [19] M. Dooms, L. van der Ugt, P. de Langen, International strategies of port authorities: The case of the Port of Rotterdam Authority, Res. Trans. Bus. Manag. 8 (2013) 148-157.
- [20] Dutt, S. (2012). Gothenburg Port Authority Climate Programme: Carbon Footprint Year 2010. Version 2 pp 1-36.
- [21] B. Fagan, The Attacking Ocean: The Past, Present and Future of Rising Sea Levels, Bloomsbury, London, UK, 2013.
- [22] C. Greene, J. Francis, B. Monger, Super Storm Sandy: A series of unfortunate events? Oceanography 26 (1) (2013) 8-9.
- [23] Hawkes, P., Pauli, G., Moser, H., Arnsten, O., Gautres, P., Mal, S. and White, K. (2010). Proceedings of ICE Civil Engineering 163 May 2010 Impacts of Climate change on water borne transport. Pages 55-63 Paper 09-00051.
- [24] Innovative Management for Europe's Changing Coastal Resource (IMCORE), (2013). <http://www.imcore.eu/index.html>.
- [25] International Association of Ports and Harbours IAPH (2008). C40 Worlds Ports Climate Conference: World Ports Climate Declaration. Downloadable at <http://wpci.iaphworldports.org/data/docs/about-us/Declaration.pdf>. Accessed 26-03-2013.
- [26] International Association of Ports and Harbours - IAPH. (2010). Seaports and Climate Change: An Analysis of Adaptation Measures. Draft Report of Port Planning and Development Committee, November 2010.
- [27] Infrastructure Australia. (2011). National Ports Strategy: Infrastructure for an economically, socially, and environmentally sustainable future, Infrastructure Australia and the National Transport Commission, Commonwealth Government, Canberra. In McEvoy, D & Mullett, J. (2013). Enhancing the resilience of seaports to a changing climate: Research synthesis and implications for policy and practice. Work Package 4 of Enhancing the resilience of seaports to a changing climate report series, National Climate Change Adaptation Research Facility, Gold Coast. pp1-49.
- [28] Infrastructure Australia (2012). National Land Freight Strategy Update, Infrastructure Australia, Commonwealth Government. In McEvoy, D, Mullett, J, Millin, S, Scott, H & Trundle, A 2013, Understanding future risks to ports in Australia. Work Package 1 of Enhancing the resilience of seaports to a changing climate report series, National Climate Change Adaptation Research Facility, Gold Coast, 77 pp.
- [29] Inoue, S. (2013). Sea ports and climate change: JRC workshop on risk assessment. Session I: Current circumstances and future prospects for Sea Ports. Conference-workshop proceedings 4-5 March 2013, MCE Brussels.
- [30] IPCC, in: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson (Eds.), Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 2007, p. 976.
- [31] IPCC, Glossary of terms, in: C.B. Field, V. Barros, T.F. Stocker, D. Qin, D. J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, P.M. Midgley (Eds.), Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, Cambridge University Press, Cambridge, UK, and New York, NY, USA, 2012, pp. 555-564.
- [32] IPCC (2013a). Working Group I contribution to the IPCC Fifth Assessment Report (AR5), Climate Change 2013: The Physical Science Basis, Chapter 04- Observations: Cryosphere - Final Draft Underlying Scientific-Technical Assessment. . Downloadable at: [http://www.climatechange2013.org/images/uploads/WG1AR5\\_WGI-12Doc2b\\_FinalDraft\\_Chapter04.pdf](http://www.climatechange2013.org/images/uploads/WG1AR5_WGI-12Doc2b_FinalDraft_Chapter04.pdf).
- [33] IPCC (2013b) Working Group II contribution to the IPCC Fifth Assessment Report (AR5), Climate Change 2013: The Physical Science Basis, Chapter 1 - Point of Departure - Final Draft Underlying Scientific-Technical Assessment. Accessed on 12/05/2014 [http://www.climatechange2013.org/images/uploads/WGIIAR5\\_WGII-12Doc2b\\_FinalDraft\\_Chapter1.pdf](http://www.climatechange2013.org/images/uploads/WGIIAR5_WGII-12Doc2b_FinalDraft_Chapter1.pdf).
- [34] IPCC (2013c). Working Group I contribution to the IPCC Fifth Assessment Report (AR5), Climate Change 2013: The Physical Science Basis, Chapter 13 - Sea Level Change - Final Draft Underlying Scientific-Technical Assessment. . Downloadable at: [http://www.climatechange2013.org/images/uploads/WG1AR5\\_WGI-12Doc2b\\_FinalDraft\\_Chapter13.pdf](http://www.climatechange2013.org/images/uploads/WG1AR5_WGI-12Doc2b_FinalDraft_Chapter13.pdf).
- [35] IPCC (2014) Climate Change 2014 Synthesis Report. Approved Summary for Policy Makers. IPCC Fifth Assessment Report (AR5), Adopted 1 November 2014. Accessed on 4/11/2014 [http://www.climatechange2013.org/images/uploads/WGIIAR5\\_WGII-12Doc2b\\_FinalDraft\\_Chapter1.pdf](http://www.climatechange2013.org/images/uploads/WGIIAR5_WGII-12Doc2b_FinalDraft_Chapter1.pdf).
- [36] P. Lu, D. Stead, Understanding the notion of resilience in spatial planning: A case study of Rotterdam, The Netherlands, Cities 35 (2013) 200-212.
- [37] D. McEvoy, J. Mullett, Enhancing the resilience of seaports to a changing climate: Research synthesis and implications for policy and practice. Work Package 4 of Enhancing the resilience of seaports to a changing climate report series, Natl. Climate Change Adaptation Res. Facility, Gold Coast (2013) 1-49.
- [38] D. McEvoy, J. Mullett, S. Millin, H. Scott, A. Trundle, Understanding future risks to ports in Australia. Work Package 1 of Enhancing the resilience of seaports to a changing climate report series, Natl. Climate Change Adaptation Res. Facility, Gold Coast (2013) 77.
- [39] McLaughlin, B., Scott, M., and DesRoches, S. (2011). Anticipating Climate Change American Society of Civil Engineers Journal 08857024. April 2011.
- [40] M.D. Morecroft, C.E. Cowan., Responding to Climate Change: An Essential Component of Sustainable Development in the 21st Century, Local Econ. 25 (3) (2010) 170-175.
- [41] D. Muir, J. Cooper, G. Pétursdóttir, Challenges and opportunities in climate change adaptation for communities in Europe's northern periphery, Ocean Coast. Manag. 94 (2014) 1-8.
- [42] A. Ng, S. Chen, S. Cahoon, B. Brooks, Z. Yang, Climate change and the adaptation strategies of ports: The Australian experiences, Res. Trans. Bus. Manag. 8 (2013) 186-194.
- [43] Nicholls, R., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Mornot, J., Chateau, R. and Muir-Wood, R. (2008). "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", OECD Environment Working Papers, No. 1, OECD Publishing. Available at: <http://www.oecd.org/dataoecd/16/58/39720578.pdf>.
- [44] A.M. O'Hagan, R.C. Ballinger, Coastal governance in North West Europe: An assessment of approaches to the European stocktake, Marine Policy 33 (2009) 912-922.
- [45] A.M. O'Hagan, R.C. Ballinger, Implementing Integrated Coastal Zone Management in a national policy vacuum: Local case studies from Ireland, Ocean Coast. Manag. 53 (2010) 750-759.
- [46] Office of Public Works (OPW). (2014). South Western RBD CFRAM Study SEA Scoping Report: Annex II The Lee Cork Harbour Catchment. Downloadable at: <http://www.southwestcfрамstudy.ie/>.
- [47] S. Park, M. Howden, S. Crimp, Informing regional level policy development and actions for increased adaptive capacity in rural livelihoods, Environ. Sci. Policy 15 (1) (2012) 23-37.
- [48] Port of Gothenburg (2012). Sustainability Report of Gothenburg Port Authority (2012). Downloadable at: [http://www.portofgothenburg.com/Documents/PDF-bank/Engelska%20filer/012-0206\\_H%3C%3A51Ibarhet\\_2012\\_GH\\_ENG\\_150\\_WEB.pdf](http://www.portofgothenburg.com/Documents/PDF-bank/Engelska%20filer/012-0206_H%3C%3A51Ibarhet_2012_GH_ENG_150_WEB.pdf).
- [49] Port of Gothenburg (2013). Sustainability Report of Gothenburg Port Authority (2013). Downloadable at: <http://www.portofgothenburg.com/Documents/PDF-bank/Engelska%20filer/gbghamn-hallbarhet2013-en-spread-100ppi.pdf>.
- [50] Port of Gothenburg (2014). Sustainable Port: Sustainability Report of Gothenburg Port Authority 2014. Downloadable at: [http://www.portofgothenburg.com/Documents/PDF-bank/Engelska%20filer/GH\\_Hallbarhetsred\\_2014\\_ENG\\_k4%20\(2\).pdf](http://www.portofgothenburg.com/Documents/PDF-bank/Engelska%20filer/GH_Hallbarhetsred_2014_ENG_k4%20(2).pdf).
- [51] B.L. Preston, R.M. Westaway, E.J. Yuen., Climate adaptation planning in practice: An evaluation of adaptation plans from three developed nations, Mitigation Adaptation Strategies Global Change 16 (2011) 407-438.
- [52] N. Ranger, S.-L. Garbett-Shiels., Accounting for a Changing and Uncertain Climate in Planning and Policymaking Today: Lessons for Developing Countries, Climate Dev. 4 (4) (2012) 288-300.
- [53] Rotterdam Climate Change Adaptation Strategy (2013). Downloadable at: [http://www.deltacities.com/documents/20121210\\_RAS\\_EN\\_Ir\\_versie\\_4](http://www.deltacities.com/documents/20121210_RAS_EN_Ir_versie_4).
- [54] Rotterdam Climate Proof Adaptation Programme (2013). Downloadable at: <http://www.rotterdamclimateinitiative.nl/documents/Documenten/ROTTERDAM%20CLIMATE%20PROOF%20ADAPTATION%20PROGRAMME%202013.pdf>.
- [55] H. Scott, D. McEvoy, P. Chhetri, F. Basic, J. Mullett, Climate change adaptation guidelines for ports. Enhancing the resilience of seaports to a changing climate report series, Natl. Climate Change Adaptation Res. Facility, Gold Coast (2013) 1-28.
- [56] Shine, T. and Desmond, M. (2011). Ireland Adapts to Climate Change: Climate Change Research Programme (CCRP) 2007-2013 Report Series No. 9. Environmental Protection Agency: Johnstown Castle Estate, Wexford, Ireland.
- [57] Smythe, T. (2013). Assessing the Impacts of Hurricane Sandy on the Port of New York and New Jersey's Maritime Responders and Response Infrastructure. Quick Response Report No. 238 to the University of Colorado Natural Hazards Center, May 31, 2013.
- [58] F. Sturt, D. Garrow, S. Bradley, New models of North Western European Holocene palaeogeography and inundation, J. Archaeological Sci. 40 (2013) 3963-3976.
- [59] UK Climate Change Act 2008, Chapter 27. Downloadable at <http://www.legislation.gov.uk/ukpga/2008/27/contents>.

- [60] UNCTAD. (2008). Review of maritime transport. United Nations Conference on Trade and Development (UNCTAD), New York.
- [61] United States Environmental Protection Agency (USEPA). (2008). Planning for Climate Change Impacts at U.S. Ports White Paper July 2008.
- [62] Van der Meer, R. (2011). Port Climate Action at Rotterdam. Report by the port policy advisor. Downloadable at: [http://www.weather-project.eu/weather/downloads/Project-Events/adaptation-workshop-may-2011-03-15/WEATHER-WS3-2011-05-20\\_12-van-de-Meer\\_Rotterdam-Port.pdf](http://www.weather-project.eu/weather/downloads/Project-Events/adaptation-workshop-may-2011-03-15/WEATHER-WS3-2011-05-20_12-van-de-Meer_Rotterdam-Port.pdf).
- [63] Vellinga T. and De Jong M. (2012). Approaches to climate change adaptation in the Port of Rotterdam. In: Asariotis R, Benamara, H. (ed) Maritime Transport and the Climate Change Challenge.
- [64] World Ports Climate Initiative (WPCI) (2008). History: How the WPCI began; Chief Goals: The Start of a Movement. <http://wpci.iaphworldports.org/about-us/index.html> Accessed at 16.04.2012.
- [65] World Ports Climate Initiative (WPCI) (2014). IAPH Toolbox for Port Clean Air Programmes. <http://wpci.iaphworldports.org/iaphtoolbox/index.html> Accessed at 08.09.2014.