Adaptation to Climate Change at Ports, Regions and Supply Chains

by

Huiying Zhang

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

I.H. Asper School of Business

Department of Supply Chain Management

University of Manitoba

Winnipeg, Manitoba, Canada

ABSTRACT

With increasing awareness of the potential impacts posed by climate change, many ports and their surrounding regions have undertaken adaptation planning and proactive actions so as to build a resilient and sustained business. However, most of them are still at the embryonic stage in understanding the problem and find it very challenging regarding adaptation planning and implementation. This thesis addresses the current issue in adaptation to climate change impacts at ports, regions and supply chains through quantitative and qualitative analyses. A global survey is designed to investigate port decision-makers' perceptions and knowledge about climate change adaption. It explores the existing impacts posed by sea level rise (SLR), and high winds and storms, and demonstrates the potential impacts of adaptation measures. Analytical results suggest that, despite the forecast of more serious impacts posed by these climate change risks in the near future, port decision-makers still have strong doubts about the effectiveness of adaptation measures and planning. In-depth interviews in a case study on Port Metro Vancouver (Canada) are conducted to further investigate the barriers (especially institutional ones) that hinder the process of climate change adaptation, and thus calls attention for its regional efforts. Based on the literature review and analysis, this study argues that a paradigm shift in adaptation planning, notably from 'go it alone' to 'collaborative' approach involving all major port stakeholders, is urgently needed. The thesis also highlights the pivotal role of tailor-made adaptation methods in accordance with a specific climate change risk in the adaptation planning. Besides, two innovative, 'paradigm shift' recommendations are proposed to climate adaptation planning: (1) a method based on usage unit to allocate investment responsibility; and (2) the establishment of a neutral agency (e.g., a collaborative network) with the power to promote the adaptation process.

In addition, a flexible combination of engagement in collaborative projects and individual efforts for ports is suggested so as to implement adaptation works.

Keywords: Port, adaptation, climate change, perception, institutional barrier

ACKNOWLEDGEMENTS

I would like to express the deepest gratitude to my advisor Dr. Adolf K.Y. Ng for his guidance, understanding, encouragement and financial support throughout my master study. He steered me in the right direction whenever he thought I needed it. I would not have been able to complete this thesis without his incredible patience and guidance. I express my appreciation to Dr. Changmin Jiang and Dr. Gary Stern for having served on my thesis committee. They have been offering valuable suggestions and comments for me to improve the thesis. I would also like to thank Dr. Victor Cui for serving on my course committee and his helpful suggestions. Again, I really appreciate all the guidance and help from my committee members.

As part of the project entitled ‘Climate Change and Adaptation Planning for Ports’, this thesis is an attempt to draw an overall picture of adaptation to climate change at a global level. My gratitude goes to the scholars for their engagement in the global survey and help in getting the valid responses from five continents. They are: Michele Acciaro (Kühne Logistics University, Germany), Austin Becker (University of Rhode Island, USA), Stephen Cahoon (University of Tasmania, Australia), Shu-ling Chen (University of Tasmania, Australia), Claude Comtois (Université de Montréal, Canada), Miguel Esteben (The University of Tokyo, Japan), Claudio Ferrari (University of Genoa, Italy), Yui-yip Lau (The Hong Kong Polytechnic University, Hong Kong), Paul T.W. Lee (RMIT University, Australia), Alessio Tei (University of Genoa, Italy), Tianni Wang (Liverpool John Moores University, UK), Zaili Yang (Liverpool John Moores University, UK) and Di Zhang (Wuhan University of Technology, China). I would also like to thank all the participants in the survey and interviews for their precious time and selfless sharing.

Thanks also go to all the professors who helped me to establish diverse knowledge (in the field of supply chain management, sociology, and economics) and develop research abilities. I would also like to thank Ms. Siobhan Vandekeere, Ms. Ewa Morphy and Ms. Irina Glikshtern for the great support. Special thanks to my family and friends who are always by my side and support me through this academic exploration.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AAPA	American Association of Port Authorities
AEP	Annual Exceedance Probabilities
BC	British Columbia
CMAP	Climate Mitigation and Adaptation Plan
DV	Dependent Variable
FCM	Federation of Canadian Municipalities
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IAPH	International Association of Ports and Harbors
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
IV	Independent Variable
SLR	Sea Level Rise
UNCTAD	United Nations Conference on Trade and Development
USA	United States of America

CHAPTER 1: INTRODUCTION

The issue of climate change has become a prominent topic in both the research community and people's daily life. Climate change does not only generate new opportunities, e.g., Arctic transportation due to global warming and ice melting (Verny, 2016) but also potentially poses significant risks and loss to the global and local economies and communities. 'Climate change impacts are characterized by multi-hazard phenomena including the simultaneous occurrence of sudden-onset hazards and creeping changes' (Birkman et al., 2010, p. 188), and the effects can be multifaceted, where changes in weather patterns directly affect the earth flora, which then has a further impact on lives of humans and animals. For instance, Nicholls et al. (2008) estimated the value of assets in large coastal cities exposed to climate change amounts to US $3,000 billion - equivalent to about 5% of the global Gross Domestic Product (GDP) in 2005. This figure is expected to reach 9% in 2070. Given such, as pointed out by Ng et al. (2016a), adaptation to climate change is a crucial issue in the global business community.

Among all of the effects associated with climate change, sea level rise (SLR) and catastrophic storms are of particular concern when it comes to maritime logistics. Because of the geographical feature of their business, seaports (hereinafter called 'ports') are much more vulnerable to climate change, compared with other stakeholders (e.g., shipping lines, inland carriers) along the maritime supply chains. Additionally, due to 'the high concentration of infrastructure and sensitive values' at ports, potential damage caused by climate change can be extremely significant (Osthorst and Mänz, 2012, p. 227).

The maritime supply chain transports more than 80 percent of the global cargo and has a significant influence on the world economy (Ng and Liu, 2014). Ports play a pivotal role in the global supply chains, as they connect ocean logistics with inland transportation which in turn, drives the growth of regional and national economies. Given that ports are the interface where goods are traded across boundaries, climate change may not only cause significant economic loss to ports but can pose further influence on the regional economy, the operation of supply chains and the social lives of people in coastal cities as well. In particular, ports and the surrounding regions would pay a high price for the serious loss caused by different climate change impacts, from the breakdown of day-to-day operations to the infrastructure damages (and repairs). Facing such risk, as noted by Ng et al. (2016b), ports must take effective actions so as to ensure smoothness of operation and service quality, especially considering that they are also key components that determine port competitiveness (Yuen et al., 2012).

In general, the approach to tackling climate change is two-fold, namely mitigation and adaptation. Mitigation seeks to prevent/slow down climate change, often through the control of greenhouse gas (GHG) emissions (Füssel and Klein, 2006). Such an approach often leads to the (targeted) development of the so-called 'green' ports (for further details, see Zhang et al., 2016). By taking this action, ports may benefit from gaining a better public image but do not necessarily address (in some cases, even pose negative effects) the need for adaptation to climate change risks (Knatz, 2016). Adaptation implies responses (e.g., technical, economic) to extreme events posed by climate change (e.g., coastal protection) (Osthorst and Mänz, 2012). Instead of eliminating climate change impacts, adaptation accepts the (at least partially) inevitable consequences and strives to build capacity and resilience so as to protect critical facilities and infrastructure, including ports, from suffering such consequences. Although some scholars have addressed ports' adaptation to climate change from various aspects - such as economy, policy, and risk (see Ng et al., 2013a, for a detailed discussion), this is still a very new, embryonic topic in port and maritime supply chain research where more attention has been paid to mitigation (Araral, 2013; Ekstrom and Moser, 2013; Walker et al., 2010). Given that the time for mitigation to take effect can be centuries (Füssel and Klein, 2006), it is crucial to undertake adaptation measures to effectively respond to climate change impacts in the foreseeable future. However, adaptation to climate change, especially at coastal regions, is a complex issue involving internal and external stakeholders, environmental and economic impacts across different scales and sectors, and collective choices on both individual and organizational levels (Brown et al., 2014; Waters et al., 2014). In this case, a major concern is that many ports (and port stakeholders) found it very difficult to get to the 'next level', e.g., fund raising, action implementation, etc. from the stage of knowledge sharing and open talk (Becker, 2016). For example, although the port of San Diego's port authority initiated the *Climate Mitigation and Adaptation Plan* (CMAP) (promulgated in 2013), it finally ended up with the suspension of the adaptation components. According to Messner et al. (2016), the lesson from the failed case of CMAP is the difficulty associated with encouraging port stakeholders to get involved, and developing effective stakeholder management for such purpose.

Nevertheless, the fast changing climatic conditions and their potential hazardous impacts give us no extra time to hesitate at or evade the issue of climate change adaptation. Several attempts have been made to highlight the role of stakeholder collaboration to address this problem. Ng et al. (2013b) highlighted the significance of 'soft' management rather than 'hard' infrastructure in the adaptation process. Past lessons from case studies suggest that one key challenge to advance stakeholder collaboration is to include the concerns of a wide variety of stakeholders and resolve the conflicts of interests (Becker et al., 2015; Messner et al., 2016). However, a systematic discussion of how to achieve stakeholder collaboration is still lacking. Another stream of literature investigates the barriers that potentially jeopardize the process of climate change adaptation. Although these barriers can be analyzed from different research angles, such as finance and technology (Klein et al., 2001; Xiao et al., 2015), problems related to stakeholders (mainly the institutional barriers) have grown in importance. To achieve collaboration among stakeholders, a number of researchers sought to overcome these barriers from an institutional perspective (Araral, 2013; Barnett et al., 2015; Garrelts and Lange, 2011). So far, however, few studies have systematically investigated institutional impacts on climate change adaptation and how institutional barriers can be surpassed to advance stakeholder collaboration.

This study attempts to (a) draw an overall picture of perceptions and attitudes that port decision-makers hold towards climate change adaptation; (b) investigate the barriers (especially institutional ones) that hinder the process of climate change adaptation; (c) provide strategic directions for future planning efforts; and (d) draw more attention from scholars and practitioners to ports' adaptation to climate change. To tackle the contemporary issue of adaptation for ports and port stakeholders, the thesis addresses the following primary research question: why do stakeholders of ports, regions surrounding the port and supply chains find it challenging to move the process of adaptation from the stage of knowledge sharing and open talks to planning and implementation? For a better understanding, secondary research questions are developed as 1) to what extent is it necessary or important for ports to plan and invest in measures so as to adapt to the potential risks posed by climate change in the foreseeable future? 2) how and why do institutions act as impediments in the process of climate change adaptation? The first secondary research question is answered by a global survey, which aims to 1) provide a holistic view of port decision-makers' perceptions on climate change adaptation, and 2) prove that decision-makers have doubts about the effectiveness of adaptation measures. The latter secondary research question is addressed by delving deep into the current phenomenon from a particularly institutional angle with theoretical analysis and a case study.

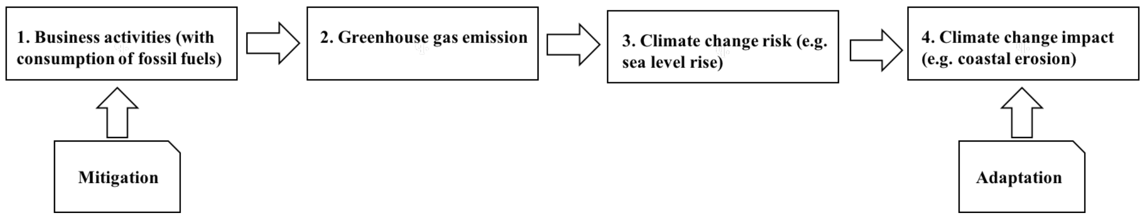
The overall structure of the study takes the form of six chapters. After this introductory chapter, Chapter 2 consists of the literature review and lays out the theoretical foundation of the following parts, while Chapter 3 introduces methodologies, including rationales and design details. Chapter 4 presents and discusses the results of the survey. Chapter 5 implements a case study of Port Metro Vancouver. Finally, conclusion, limitations, future research directions and implementations can be found in Chapter 6.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Business activities take advantage of public resources (e.g. water and air) but are also affected by natural conditions. Topics of economy-environment interactions have been studied by many scholars and climate change is at the forefront of this academic field. Changes in climatic conditions have imposed different impacts on various business sectors, for example, agriculture, forest management, and maritime supply chain (Becker et al., 2012; Bouriaud et al., 2015; Chhetri et al., 2010).

Academia is aware of the significance of climate change studies. To address the rising issue, approaches to mitigation and adaptation have been developed. Figure 2.1 illustrates the causality in climate change scenario at ports on the basis of previous works, in attempting to enhance our understanding of the relationship between mitigation and adaptation methods. Mitigation strategies tackle the problem from its source by changing climatic conditions, which in many cases include regulating or adjusting business activities (at Stage 1). Adaptation deals with this issue by accepting the impacts already or potentially posed by climate change (at Stage 4) and making efforts to moderate harm through modification of the current system (Becker et al., 2012; Nursey-Bray et al., 2013). Despite of their dissimilarity in nature, 'mitigation and adaptation are not mutually exclusive' (City of Vancouver, 2012, p. 4), or mutually isolated. Indeed, mitigation will have impacts on adaptation through the causal line and in practice, mitigation and adaptation can both benefit from a particular measure addressing climate change. Currently, the Five Milestone Process proposed by the International Council for Local Environmental Initiatives (ICLEI) Canada and the Federation of Canadian Municipalities (FCM) (2008) is the guiding framework for mitigation efforts of ports. It follows a 'top-down' approach with five steps: (1) creating a baseline for emission; (2) setting a goal for the forecast year; (3) developing a corresponding action plan; (4) implementing this action plan; and (5) monitoring and assessing the whole process.

Figure 2.1. Causality in climate change scenario at ports



Compared with the long history of mitigation approaches, it is widely agreed that adaptation to climate change is in its infancy (Araral, 2013; Ekstrom and Moser, 2013; Walker et al., 2010). Lacking experience, ports and other stakeholders use mitigation method as a reference and find themselves in a dilemma: in contrast with a high level of consensus on the significance of adaptation measures and a moderate degree of ability to draw guidelines and develop adaptation plans, the implementation capability remains low (Lemieux and Scott, 2011). It is relatively straightforward to conduct research to learn and understand adaptation circumstances. However, how to progress from a conceptual and planning stage to a practical and implementing stage remains a serious challenge. Hence, collaborative work with the engagement of most (if not all) stakeholders is highly valued (Becker et al., 2013).

Adaptation to climate change, especially at coastal regions, is a complex issue (Brown et al., 2014; Waters et al., 2014). One reason is the regional nature of adaptation efforts. With this very nature (different from mitigation that tries to achieve certain milestones in GHG emission), the goals of climate change adaptation, including those of the ports, strongly depend on local conditions and circumstance (Peñalba et al., 2012). Ports located at different regions need to tackle different risks: SLR is identified as the primary risk for the Port of San Diego (USA) (Messner et al., 2016); the Port of Montreal (Canada) focuses on dropping water level along the St. Lawrence River (Slack and Comtois, 2016); while the ports along Tokyo Bay (Japan) need to deal with strong typhoons (Esteban et al., 2016). Due to this regional nature, adaptation planning and enforcement must involve engagement from various stakeholders. However, stakeholders of ports have encountered difficulties with the implementation of adaptation plans. Barriers in the process of climate change adaptation need to be identified to tackle this problem.

Academia generally agrees on the definition of barriers to climate change adaptation as obstacles and constraints that impede the adaptation process (Eisenack et al., 2014; Moser and Ekstrom, 2010; Waters et al., 2014). It is notable that barriers and limits are inherently different in terms of whether they can be overcome or surpassed (Eisenack et al., 2014). Moser and Ekstrom (2010, p. 22027) defined barriers to climate change adaptation as 'obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, etc.'. With increasing awareness that barriers can be prioritized differently in different sectors by various actors (Waters et al., 2014), elements such as actor (a barrier that is challenging to one actor may be beneficial to another) and context (barriers may vary among different situations) were added so as to refine the definition and reflect its complex nature (Eisenack et al., 2014).

There is an increasing body of literature that addresses barriers to climate change adaptation. Ekstrom and Moser (2014) grouped the most common barriers into four types: institutional, attitudinal, financial and political, while Waters et al. (2014) reviewed the literature and categorized groups as institutional, social and cognitive, uncertainty-related and cost-related.

Moser and Ekstrom (2010) proposed a systemic framework to identify such barriers in the three phases of climate change adaptation: understanding, planning, and managing. Subsequently, they applied it to adaptation work in California, USA and pointed out the pivotal role of institutions and governance-related issues as obstacles in climate change adaptation. Institutional barriers were reported as the most common ones among the 12 categories in their study. Through five case studies in the San Francisco Bay Area, they argued the importance of institutional lens to further investigate barriers in the process of climate change adaptation (Ekstrom and Moser, 2013). Their finding was supported by other scholars through empirical analyses. Klein (2016) revealed the embeddedness of climate change adaptation into the local context in Finland, while Lawrence et al. (2015) studied adaptation works in New Zealand from the angle of institutional analysis. Walker et al. (2015) highlighted crucial governance barriers to deal with climate change risks in transport planning in England. Institutional capacity was identified as a key enabler to overcome barriers in the process of climate change adaptation by taking full advantage of the existing resources, rather than tackling the problem of insufficient resources (Amundsen et al., 2010; Burch, 2010).

With increasing evidence highlighting the critical role of institutions in influencing adaptation to climate change, researchers studied the institutional impacts from a wide range of theories. Marshall (2013) applied transaction cost theory to build a framework for institutional cost and benefit analysis, with a focus on path dependency that constrains adaptation management. Peñalba et al. (2012) discussed adaptation efforts in the Philippines from social and institutional perspectives and argued the pivotal role of cognitive enhancement and adaptive capacity building. A comprehensive model (the COW model) was developed by Araral (2013) by synthesizing core views from three fields: Coase's property right, Ostrom's governance principles for the public good and Williamson's transaction cost. Through a case study, he verified the effectiveness of this model and proposed six institutional design principles to reduce transaction cost in the adaptation to climate change. Similarly, Brunner and Enting (2014) suggested incomplete institutions and incomplete information as obstacles in climate finance from the angle of transaction cost. In particular, unclear property right and vague responsibility allocation were categorized as two major aspects of incomplete institutions.

The second body of literature studying institutional impacts on climate change adaptation was developed using a particular theory on institutionalism. By adopting path dependency, Garrelts and Lange (2011) attested to the central role of the government in climate change adaptation in the German flood management system, and also emphasized the functions of other stakeholders (i.e. academia, the media) to offer support and knowledge. Chhetri et al. (2010) examined how path dependency limited farmers' choices to adapt to climate change and proved sub-optimal outcomes were inevitable due to institutional impacts. Barnett et al. (2015) investigated the drivers of barriers to climate change adaptation and identified path dependency in institutions as the primary reason.

Nevertheless, the connection between climate change adaptation and institutionalism is not clear (Araral, 2013). The first branch of literature covers a broad range of theories and 'borrows' relevant insights to address institutional obstacles in the process of climate change adaptation. This vast reference and discussion have a risk in mismatching theoretical framework with empirical evidence in an inadequate way (Kingston and Caballero, 2009). The second part narrows down the theoretical foundation to path dependency but such 'zoom out' may neglect other significant influences that institutions have on climate change adaptation, thus failing to explain institutional barriers from a holistic view. In particular, it is not adequately addressed in what way and to what extent institutions matter in climate change adaptation. This chapter critically reviews the impacts of institutions on the process of climate adaptation planning by analyzing their key themes and proposes a constructive suggestion on how the institutional structure of planning should change in an attempt to fill the gap and achieve a breakthrough.

Adaptation may appear straightforward (Walker et al., 2010) but in practice is an intricate action system: it requires heterogeneous resources (e.g. time, money and people), inputs from different scales and collaboration from various sectors. Walker et al. (2010) conducted a general review of the literature on climate change adaptation, and they proposed three themes: uncertainty, indirect benefits and planning horizons. Their idea is employed to introduce the distinct features of climate change adaptation and explain why institutions can be impediments in the adaptation process.

The most inherent problem associated with climate change is its uncertainty. Uncertainty is intrinsically different from risk. Risk is defined as ‘the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery’, while uncertainty is ‘an expression of the degree to which a value or relationship is unknown’ (IPCC, 2012, pp. 564, 558). In other words, compared with uncertainty, risk is a relatively static concept (Scholz et al., 2012) and can be seen as ‘known unknowns’: we know the probability of an uncertain event that may occur in the future and the distribution of possible outcomes. Simultaneously, uncertainty is ‘unknown unknowns’: due to the lack of applicable techniques, we do not know or find it difficult to get a reliable estimation of when an event will happen based on past incidents, what impacts it will bring, how serious the damages could be and whether the adaptation measure will take effect. In the context of climate change adaptation at ports, empirical analyses (case studies) highlight the significance of stakeholders' knowledge to facilitate their decision-making process. Indeed, most of the adaptation efforts are at the stage of open talks and impact analysis. Insufficient and unreliable knowledge results in 'predictive uncertainty'. Adaptation to climate change is a reflection of time series: from past experiences, we predict and prepare for the future and take actions at present. However, scientific tools are not sufficiently developed to provide robust predictions, especially in terms of impact assessment and economic evaluation. Incomplete information hinders the decision-making process of climate change adaptation, as stakeholders doubt the reliability of projections.

Another crucial feature of climate change adaptation is immeasurable and indirect benefits. To examine and demonstrate the effectiveness of mitigation measures, the cost per ton in emission reduction can be calculated (Ritchie et al., 2005). However, how to define the effectiveness of adaptation actions is still under debate. The benefits are very difficult, if not possible, to measure. For example, a dike cannot be evaluated if no flood occurs in the next 20 or 50 years. Even if a flood occurs, it is still debatable to what extent the dike protects the floodplain and what the associated benefits are. On the other hand, benefits of climate change adaptation are indirect: due to the potentially long time horizon for adaptation actions to take effect, individuals or organizations that invest in an adaptation plan may not be the ones who receive the benefits (Walker et al., 2010). In addition to the time scale, indirect benefits can also be viewed from the angle of span. Adaptation works can be beneficial not only to the ones who make efforts (invest) but also to a different group at the same time. This inevitable 'externality' result in a ‘tragedy of the commons’ (Dietz et al., 2003). Instead of being positively engaged in adaptation efforts, stakeholders prefer to wait for others to act and benefit from the ‘free ride’.

The long time horizon is another feature that makes climate change adaptation efforts special, given the fact that the expected lifespan of a climatic-sensitive infrastructure/building is 50-200 years (Hallegatte, 2009). This time period simultaneously intensifies the other two characteristics of climate change adaptation. Adaptation works may pay off in the long run (relative to human life cycle and political life); thus there is a possibility that these efforts may not be effective even after their periods of depreciation[1]. Similar with indirect benefits, the long time horizon drives uncertainty in the cognition of stakeholders and the decision-making process. To further understand how institutions affect the process of climate change adaptation, key streams and concepts in institutional theories are briefly reviewed.

Institutions refer to the formal and the informal rules that confine and guide human behaviors (Brunner and Enting, 2014; Denzau and North, 1994; Roberts and Greenwood, 1997). Formal rules, such as laws and regulations, are explicit and set by legislators to govern strategic choices of actors through various interventions and arrangements; while informal norms, primarily customs, traditions and other social orders, are implicit and developed through interactions between actors (Tongzon et al., 2015). Institutions have the power to guide and induce certain patterns or codes of behaviors. Institutionalization is defined as the process that shapes or embeds the behavior of actors into the governance which operates in the economic, political and cultural landscapes that institutions generate and develop (Badie et al., 2011). It is also used to describe ‘the emergence of orderly, stable, socially integrating patterns out of unstable, loosely organized, or narrowly technical activities’ (Broom and Selznick, 1955, p. 238).

[1] The value of a physical construct is regarded as zero in fiscal setting after the period of depreciation.

A considerable number of scholars have studied the mechanism of institutionalization from different angles. Badie et al. (2011) identified rational choice institutionalism and sociological institutionalism as the two pillars of institutional theories.

The rational choice approach studies the interplay of institutions and actors' behaviors from an economic perspective. In the rational choice institutionalism, the actor is a rationalist, whose aim is to maximize utility and advance his/ her own interests (Pierson, 2000). Under this circumstance, expected outcomes are set and then pursued. When setting targets, actors conduct evaluations of costs and benefits for different options. There is a tendency to prioritize their options bounded by a specific institutional setting. As a result, the rational actors prefer to achieve targets that are somewhat 'within their reach', rather than to strive for less certain outcomes. In such a setting, institutions are more concerned with self-interest fulfillment, relative to long-term planning (which is difficult to anticipate effects, especially in a dynamic environment) or the more ambiguous outcomes. Plans over relatively short time horizons are also more likely to provide short-term results. This is especially important in a political situation, due to the constraints of an electoral system with a typical political life of 5 years. Thus the potential returns drive politicians to focus on short-term projects and demonstrate their achievements while in power. At the same time, institutions evolve in accordance with actors' behaviors based on functionalism (Roland, 2004). That is to say, rational choices generate institutions and develops them cumulatively.

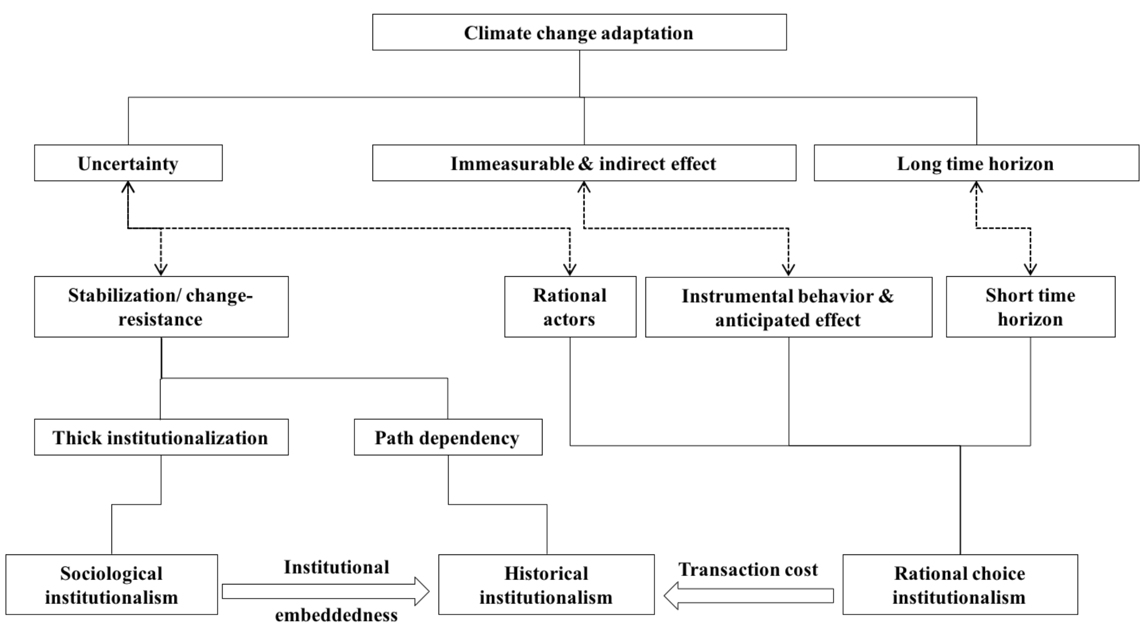
The other stream of literature shifts major concerns from rational choices to values and beliefs. The significance of values and beliefs in the decision-making process is highlighted by 'thick institutionalization'. Selznick (1994) suggested that institutionalization can be analyzed using two different procedures. At first, formal institutions are established during the planning and design phase. However, these formal rules are so high-level that they can be regarded as a thin layer (Badie et al., 2011). In the subsequent implementation phase, formal structures and rules are applied to a culturally-specific environment and interpreted by actors in accordance with their values and beliefs (informal institutions). Afterwards, outcomes and assessments will in return have impacts on informal rules (Walker et al., 2015). This second step is, therefore, critical to the institutionalization process. At the implementation stage, actors take adaptive measures and make 'real' changes through institutional learning.

Institutions develop thoughts and compose cognitive patterns accordingly. Instead of arguing that institutions are products of actors' behaviors, sociological institutionalism emphasizes the embeddedness of institutions in operations and organizations and how this kind of embeddedness can influence the decision-making process. In most cases, decisions based on rational choices are made to advance the interests of a single party which then may negatively impact the interests or power of others (Notteboom et al., 2013). Stakeholders must resolve conflicts of interests through negotiation. Hence, actors in the bounded social environments seek approaches that they deem appropriate. This is referred to 'logic of appropriateness' (Pierson, 2000, p. 478). In other words, the existing institutional arrangements (e.g. policies and systems) are not necessarily the most efficient or effective approaches, but instead the 'proper' interventions in the cultural environment (Hall and Taylor, 1996). On the one hand, when making decisions, actors have limited available options because their mindsets are restricted by institutions and the specific environment. Actors take these options for granted and alternative designs may not, therefore, be recognized (the so-called 'pre-conscious institutionalization' by Roberts and Greenwood (1997)). On the other hand, the 'post-conscious institutionalization' suggests that although actors realize the existence of alternative options, they tend to constrain these options to a limited range, and each of the options will result in minor changes that are acceptable under the cultural-bounded circumstance. Actors prefer conventional options that they are familiar with and 'good at'. It is possible for them to avoid mistakes and the subsequently negative consequences by following such tendency. This explains why the institutional form is likely to persist (Keohane and Victor, 2011). Indeed, institutions have the feature of inertia, stabilizing processes and preserving former designs.

Historical institutionalism addresses the issue of 'institutional plasticity' (Notteboom et al., 2013) by bridging rational choice institutionalism and sociological institutionalism. It advocates that the current institutions are evolved highly depending on institutional legacies. The core concept in historical institutionalism is path dependency: 'what happened at an earlier point would affect the possible process and outcomes of a sequence of events occurring at later time' (Tongzon et al., 2015, pp. 2-3). In this case, one decision at the beginning (that forms institutions) creates trajectories that subsequent events will follow. From the perspective of sociological institutionalism, former institutional arrangements set specific institutional and organizational goals, which then bound and shape decision-makers' values and beliefs. From the rational choice side, conventional approaches may generate returns (even if these approaches are not the most efficient), thereafter provide incentives to actors to fulfill their anticipated targets at an acceptable level. However, those trajectories do not necessarily contribute to positive feedbacks. When internal and external environments change, established rules and practices may not work properly and can potentially result in losses. Under such conditions, institutions can even be change-persistent, if the transaction cost of switching the current institutional arrangements to the alternatives is higher than losses associated with the conventional approaches. The self-reinforcing mechanisms raise the situation of 'lock-in': it is difficult, if impossible, to withdraw adopted options (Scott, 2014). Thus, path dependency is an efficient institutional tool to analyze and explain why institutions are change-resistant. It also provides insights into why incremental modifications, rather than aggressive amendments or reformative measures, are more likely to occur within institutions.

Why institutions can act as barriers in adaptation process is discussed by linking and comparing the natures of climate change adaptation and institutions. The study adopts the three aforementioned features of climate change adaptation: uncertainty, immeasurable and indirect effect, and long time horizon. In terms of institutionalism, key characteristics based on a review of different institutional theories are proposed: 1) rational actors, 2) instrumental behavior and anticipated effect, 3) short time horizon and 4) stabilization & change-resistance. Figure 2.2 illustrates the contrary nature of climate change adaptation and institutions.

Figure 2.2. Contrary nature of climate change adaptation and institutions



Climate change is dynamic. However, institutions are usually change-resistant (Pierson, 2000). Indeed, institutions are designed and evolved to avoid uncertainty by stabilizing processes in a given community (Dietz et al., 2003). Institutions cannot, therefore, evolve concurrently with climate change. Another concern about uncertainty in climate change adaptation is that rational actors are unwilling to invest in projects when returns are uncertain. They prefer work which guarantees (at least at a high level that is acceptable) a return so as to advance their associated interests. Hence, stakeholders lack the motivation to engage in climate change adaptation. The difference in outcomes can further explain decision-makers' concern regarding the effectiveness of climate change adaptation. Decision-makers desire instrumental behaviors (which help actors to reach their goals) and measurable effects to demonstrate their accomplishments. However, the immeasurable and indirect results of climate change adaptation efforts are difficult to quantify. This is especially significant when one considers that these projects can cost millions of dollars. Hence, rational actors will not commit to any significant effort for climate change adaptation measures. Another impediment is associated with the time horizon. The typical 5-year political life raises the problem of 'electoral death' and then triggers short-term decisions (Pierson, 2000). Decision-makers fear making mistakes and being subject to the subsequent consequences while in power. This is amplified by the daunting cost of adaptation measures. Differences in time horizons also provoke problems of time inconsistency: 'it may be rational for an actor to make an agreement, but equally rational to subsequently break it' (Pierson, 2000, p. 480). Former decisions can be changed over time, especially in the political environment. Time inconsistency is particularly important when dealing with climate change adaptation measures, given that climate change is typically considered a public issue and governments play a crucial role in the adaptation plans. As representatives of specific interest groups, it is reasonable to regard politicians as rational actors. When regimes shift or conditions change, political priorities can be replaced and policies regarding long time horizon effect could consequently be overturned. The Port of Gulfport (USA) has witnessed the time inconsistency when the port authority decided to re-allocate funds away from a port elevation project – only one day after Hurricane Sandy hit the Greater New York Area – to create new business and jobs (Becker et al., 2015).

The contemporary governance mechanism heavily relies on voluntary, network-based processes with stakeholders from public and private sectors (Becker, 2016). Lack of coherent guidelines and regulations makes it difficult to establish a hierarchical governance structure. However, the fact that institutions can act as barriers to the process of climate change adaptation does not necessarily mean that institutions cannot perform as enablers in adaptation efforts. Root et al. (2015) highlighted the roles of governance to tackle the financial constraints in adaptation planning. Huntjens et al. (2012) proposed eight principles of institutional design in adaptation to climate change, namely: 1) defining boundaries clearly; 2) (re-)distributing risk, benefits, and costs equally and fairly; 3) collective choice arrangements; 4) monitoring and evaluating the process; 5) developing mechanisms for conflict prevention and resolution; 6) nested enterprise/polycentric governance; 7) developing robust and flexible process; and 8) policy learning.

Organization is the exterior reflection of institutional form. In reality, organizations such as councils exist to facilitate the process of climate change adaptation. However, observations reveal that these agencies find it very challenging to advance the project from the phase of knowledge sharing and exploration to the next stage of feasible strategies and plans as well as implementation. Stakeholders from various business sectors and different levels of governments prefer open talks but are unwilling to perform as the champion to progress the project. Unfortunately, these organizational and institutional efforts fail to resolve the contemporary dilemma in climate change adaptation (at least up to now). This chapter also points out the institutional deficiencies of the current network by adopting the theory of thick institutionalization.

Thick institutionalization is not a new topic in port business. Tongzon et al. (2015) explained port reforms by employing this concept. In the recent decades, major ports around the world have undertaken reforms in ownership structures and operation principles (Cullinane and Song, 2002) so as to cope with the new business environment by enhancing efficiency and reducing cost (Cullinane and Song, 2002; Ng and Liu, 2014). Governments develop the reform models and the rules (e.g. privatization), while port authority acts as the executor and implements the established plans. Despite the fact that privatization (the formal institution) is well established, the unified solution still led to different reform outcomes (Ng and Pallis, 2010) under diversified economic, political, social and cultural environments.

Turning to the field of climate change adaptation, the effect of institutional legacies is largely magnified. The problem is two-fold: doubts about the roles of stakeholders and the loose framework. Unlike port reform, responsibility allocation is still uncertain; thus stakeholders are not sure what role they should play. Therefore, it is urgent to develop a robust framework to guide strategic actions. However, who should perform as the leader of the first stage of thick institutionalization is under debate. The government is still feeling its way around, and adaptation is not a priority for private agencies like the port authority. Evidence at the Port of San Diego (Messner et al., 2016) demonstrates that the port authority took the lead to develop a framework but ended up suspending the project. Given the insufficient experience in climate change adaptation, the port authority depended heavily on its conventional approach when designing plans and failed to take interests of other stakeholders into consideration. Such loose framework subsequently leads to unsystematic implementation. Individual participants interpret the formal institution (if there is any established one) in accordance with their own institutional learning. Nevertheless, the synthesized effect of diversified institutional environments and the path-dependent feature in implementation determines the fact that it is very difficult to achieve satisfactory outcomes for each stakeholder. In this regard, decision-makers from various agencies can barely agree on a particular framework, which explains why the effort in adapting to climate change stagnates on the phase of open talk and discussion. As discussed, climate change adaptation and institutions share contrary natures. When the external forces (e.g. the need for climate change adaptation) 'collide' with the well-developed institutions, the loose framework is not powerful enough to make aggressive progress in implementation.

Organizations such as councils gather stakeholders together with the aim to build a framework, but they fail to solve the issues of responsibility allocation and diversified informal institutions. In the network established by the council (see Figure 2.3), stakeholders are independent and exclusive from each other. As a result, they share limited institutional learnings and strategic behaviors, as well as values and beliefs. This network raises the problem of interest conflictions, disagreement on responsibility allocation as well as different interpretations of guidelines and frameworks. Understanding the institutional incompetence, a constructive suggestion (see Figure 2.4) is proposed on how the institutional structure of planning should change so as to achieve a breakthrough. Different from the existing voluntary network, the proposed network partially merges into the stakeholders from both the organizational structure and institutional mechanism. The partial merge offers an opportunity for interest integration and cognitive unity. Hence, the proposed network is equipped with the power to progress adaptation process through hierarchical interventions, but it also provides room for autonomous and flexible processes to each stakeholder.

Figure 2.3. The current network of stakeholders in collaborative work to address adaptation to climate change

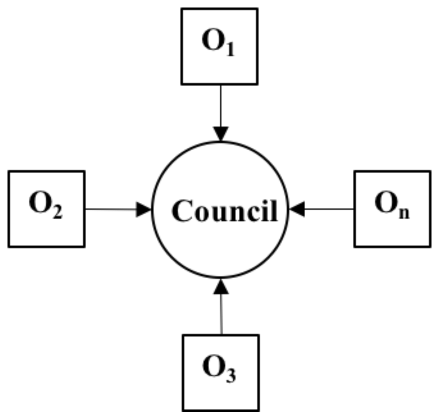
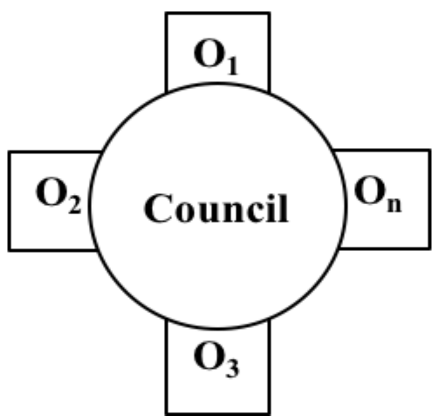


Figure 2.4. The proposed network of stakeholders in collaborative work to address adaptation to climate change



Note: O_1, O_2, and O_3 stands for organization 1, 2, 3, respectively. O_n is the last involved individual organization and n can be any natural number larger than 1.

The literature also emphasizes the importance of informal institutions in the adaptation process. Some studies investigated the impacts of informal institutions on climate change adaptation at ports. Becker et al. (2012) advocated that they took the pioneer step in addressing the field of the global survey on climate change adaptation. There were similar studies on a smaller scale. For example, a survey was conducted by a research group from Texas A&M University which only targeted US ports. With half of the respondents reporting that climate change would pose a negative influence on their port business, while adaptation planning was scarcely undertaken. Two other surveys were conducted at ports in California, USA. They found that impacts posed by climate change (mainly SLR) were not properly considered and addressed. The survey conducted by Becker et al. (2012) covered a broad diversity of port authorities by sampling ports under various geographical conditions from both developed and developing countries. The results suggested that ports across the world were, in general, aware of the potential impacts posed by climate change. The participants also agreed on the needs to take adaptation measures to respond to these potential impacts. Another survey (Ng et al., 2016a) explored the attitudes and actions of port decision-makers in adaptation planning to climate change at 21 Canadian port authorities (including seaports and dry ports). They found that adaptation was expected to be effective in moderating the potential impacts caused by SLR.

While these researchers have attempted to investigate port decision-makers' attitudes and knowledge on climate change adaptation, a comprehensive study sampling ports across the world is still lacking. The study is required to reveal whether more serious impacts posed by climate change are forecasted in the future and whether adaptation measures are believed universally to tackle such impacts effectively. Given the fact that best practice is recognized as an important approach to develop adaptation plans, regional analysis (to identify if there exist any diversification among different regions) is particularly crucial for port decision-makers to adopt this method appropriately when initiating such plans. This thesis is designed to address this gap. Another rationale for this study is that 'understanding adaptation as an ongoing process of learning is relevant for local and regional scale decision-making' (Fünfgeld and McEvoy, 2011, p. 6). Port decision-makers might have learned valuable lessons from climate change impacts and the associated damages to port and port infrastructure in the recent years, notably from the Hurricanes Katrina and Sandy in 2005 and 2012. The attitudes towards climate change adaptation might have consequently changed. Hence, it is critical to conduct a reinvestigation. Here the study proposes two hypotheses presented as follows:

Port decision-makers believe that:

H_1: If there is no adaptation measure undertaken in the near future, climate change will pose more serious impacts to ports.

H_2: Adaptation measures will be effective in enhancing the resilience of port facilities and infrastructure.

CHAPTER 3: METHODOLOGY

This thesis adopts a combination of quantitative and qualitative methodologies so as to tackle the research question with proper analytical tools. To facilitate the study process, an exploratory survey is designed to test the hypotheses and explore the perceptions that port decision-makers hold towards impacts of climate change on port operations. The rationale to choose a survey as the research methodology is that it is relatively easy to get responses from different ports around the world. Given the fact that adaptation is quite a new research topic, limited databases are available. Afterward, a case study is conducted to justify the proposed theoretical framework and further investigate why institutions act as barriers in the process of climate change adaptation. Adaptation is a regional issue and heavily depends on local environments. This, together with the need for greater input of local knowledge (UNCTAD, 2012), makes the in-depth case study very relevant. As noted by Tellis (1997), it is a useful technique to profile the current worldwide situation, while simultaneously allows researchers, policymakers, and industrial practitioners to study specific ports case by case.

3.1 Survey

3.1.1 Targeted ports

It is important to note that 'in 2011, a total of 60% of the volume of world seaborne trade was loaded and 57% was unloaded in developing country ports' (Becker et al., 2013, p. 687). A study by Nicholls et al. (2008) demonstrated that by 2005, the top ten port cities regarding exposed population to climate change (Mumbai, Guangzhou, Shanghai, Miami, Ho Chi Minh City, Kolkata, Greater New York, Osaka-Kobe, Alexandria and New Orleans, p. 7) were located in both developed and developing nations. If the 136 port cities were evaluated in the content of exposed assets, the distribution would be heavily weighted towards the developed countries. Surprisingly, 60% of the exposed values were only from three developed countries, with the new top ten cities identified as 'Miami, Greater New York, New Orleans, Osaka-Kobe, Tokyo, Amsterdam, Rotterdam, Nagoya, Tampa-St Petersburg and Virginia Beach' (Nicholls et al., 2008, pp. 7-8). The survey conducted by Ng et al. (2016a) can serve as a good start to investigate the perceptions of port decision-makers on climate change adaptation. However, Ng et al. (2016a) focused only on Canadian ports. Considering the regional nature of the adaptation measures, whether their results are extendable to ports in other countries is questionable. Hence, this thesis will target ports in both developed and developing countries. The standards used to distinguish developing nations from the developed ones were derived from The World Factbook by the Central Intelligence Agency (Central Intelligence Agency website).

3.1.2 Sampling and participants

This survey focuses on ports located on coastal lines and a few inland terminals. Becker et al. (2012) offered useful insights in attempting to reach out to targeted ports. They contacted 1,056 ports listed by the WorldPortSource in 2010, but it turned out to be impractical. Thus, they redirected their survey to include 342 business ports. These ports were members of the major port organizations, such as the International Association of Ports and Harbors (IAPH) and the American Association of Port Authorities (AAPA). Taking time cost, reliability, and representativeness into account, this study started with a strategy by initially reaching out to the decision-makers of the major port organizations. The non-probability sampling technique 'Snowball sampling' was adopted, where participants were invited to recommend potential ports (and port decision-makers) that might be interested in getting involved in this survey. As the study aims to obtain an overall view of port decision-makers' perceptions towards climate change adaption, the targeted respondents were typically port presidents, directors of strategy and business development, engineers, environmental managers and so on.

Before sending out survey invitation emails, a preliminary test was conducted by a group of experts for clarity and conceptual appropriateness, as well as to determine how long the questionnaire should be. Feedbacks from these experts contributed to the refinement of the survey questionnaire. A total 100 invitations (through an online survey on Survey Monkey and, in some cases, direct mails) were sent out to ports located in five continents towards the end of 2014. To enhance the response rate, the Dillman total design survey method was employed (Hoddinott and Bass, 1986). For those who did not provide a response, a second mailing of survey links and a cover letter were sent out approximately one month after the initial mailing. After six months, the author managed to receive 82 replies with a response rate of 82%. After the initial data screening process, 67 responses were deemed complete and valid and only these valid responses were included in the analysis in the next Chapter.

Among the 67 valid responses, 58% were from Asia and 21% were from North America. The percentages of the responses from South America, Australia, and Africa were below 5%, as shown in Table 3.1. The result reveals that the distribution of the respondents is rather concentrated. Despite all this, the author believes that this study can provide an overall picture of ports' adaptation to climate change around the world. Among all the responses with specified locations, 57 (90%) were from developed countries and regions and 6 (10%) from developing countries (responses from Mainland China and Hong Kong were separated into different categories).

Table 3.1. Geographical distribution of valid responses

REGION	COUNTRY/REGION	VALID RESPONSE(S)	PERCENTAGE
Asia	Taiwan	15	22%
	China (incl. Hong Kong)	17	25%
	Japan, South Korea, UAE and the Philippines	7	10%
North America	USA	1	1%
	Canada	13	19%
Europe	France, Italy, Germany and the Netherlands	6	9%
Latin America	Peru	1	1%
Australasia	Australia	2	3%
Africa	South Africa	1	1%
Not specified[2]		4	6%
TOTAL		67	100%

3.1.3 Selected climate risks

Given the fact that there is a broad range of climate risks to ports, e.g., drought and flooding, it is difficult to address all of them in one single survey. The targeted ports are located all around the world (as shown in Table 3.1), so the climate risks covered need to be universally common. In the survey by Becker et al. (2012), the participants were asked to rank three top concerns about climate change. SLR was prioritized as the most significant (listed by 52% of the respondents), following by ‘storm impacts’ (chosen by 45% of the respondents). Becker et al. (2013, p. 686) demonstrated that ‘between 1960 and 2010, at least one tropical storm passed within 50 km of 32% of the world seaports’. Thus, it is a sensible choice to select SLR and storms, including high winds, as the climate change risks for this study.

[2] Due to the sensitive nature of the issue, some ports are unwilling to release their identity, even on which continent their ports are located.

3.1.4 Questionnaire design

The survey (see Appendix A for details) was designed as an attempt to test the two hypotheses. The first independent variable (IV) is time, categorized as binary: in the past five years or the predicted future. Given that the aim of this thesis is to try to identify the differences in impacts without interventions, it was assumed there were no future adaptation measures. The dependent variable (DV) is the severity of each impact posed by climate change. Turning the attention to the second hypothesis, IV is a categorical variable, whether or not future adaptation measures will be taken. DV is the level of climate change impacts. Adaptation plans are the corresponding measures (or planned measures) to each of the selected impacts. The measurement of DV contains three risk parameters, 1) timeframe (when you expect to see the impact of climate change for the first time), 2) severity of consequences, and 3) likelihood (that the event will occur).

This questionnaire consists of three scenarios: (a) the current situation; (b) the future (in the coming decade) without developing any adaptation measures; and (c) the future with adaptation measures developed. This design aims to achieve the research goal of drawing an overall picture of perceptions and knowledge that port decision-makers hold towards climate change adaptation. The current situation is what these decision-makers have experienced; thus it has a significant influence on perceptions. The two different scenarios in the future reflect their knowledge of climate change risks and expectations. Therefore, all the three scenarios should contribute to enhancing our understanding of port decision-makers' attitudes and knowledge.

The response to each question is arranged on a Likert scale. For example, frequency of high waves caused by SLR falls into five levels (see Appendix A for details). The option 'I do not know/I am not sure' was added to the existing risks to further investigate their perceptions.

As port adaptation to climate change is a rather new topic, few approach can help us to quantify or monetize the impacts especially in terms of severity of consequences. It is sensible to collect ordinal data to obtain the 'fuzzy' opinions of port decision-makers (Yang et al., 2015).

3.1.5 Statistical test

A sign test can be used for the comparison between two groups of ordinal variables (McCrum-Gardner, 2008). It typically examines the difference before and after treatment; therefore it is a pair-wise comparison. Given that the data is skewed (based on the observations from histograms, to be illustrated later in this study), a sign test is an appropriate approach for the hypothesis testing as it has no assumption on a symmetric distribution. Table 3.2 further explains why sign test is considered a proper tool for this study. Statistical software Stata 12 is applied to conduct the sign test. The responses in the category of 'I do not know/I am not sure' were excluded from the sign test, which is an accepted method of dealing with the missing ordinal data (Heir and Weisæth, 2006).

Table 3.2. Hypothesis test issues and sign test solutions

ANALYSIS CONCERNS	SIGN TEST SOLUTIONS
The data is ordinal; thus there is no meaning to calculate a mean for a statistical test. Instead, a median is usually applied.	A sign test examines whether the difference of two medians is zero.
Comparison between pair data should be conducted to identify the difference between 1) the past and the future without adaptation; 2)the future with adaptation and the future without these measures.	A sign test is a pair-wise test.
The data is pre- and post-treatment results of the same participants. In other words, the result data is from the same survey participants, rather than two independent group members with and without treatment.	A sign test targets on the same sample pool.

3.2 Case study

The case study chapter examines the adaptation efforts aiming at tackling issues posed by climate change at Port Metro Vancouver (PMV), Canada. Located along the southwest coast of Canada, PMV is the third largest ports in North America in terms of tonnages (inbound and outbound). As the largest port in Canada, PMV sets its vision as 'to be recognized as a world class gateway by efficiently and sustainably connecting Canada with the global economy, inspiring support from our customers and from communities locally and across the nation' (PMV website). Sustainability is the core value that inspires PMV's development (PMV website). In economic terms, PMV facilitates about 20% of goods that are moved and traded across Canada (PMV website). As with many other ports around the world, PMV is exposed to climate change and consequently, facilities and infrastructure in its jurisdiction are at substantial risk. Thus, the case of PMV can effectively explain why decision-makers find it difficult to move from the stage of planning to funding and implementation.

During the process of document review, it is recognized that it is difficult to get access to information about climate change adaptation at PMV, nor does a research focusing on PMV concerning climate change adaptation exist (to the author's best knowledge). Likely reasons behind this phenomenon may be that 1) adaptation strategies are not well developed at PMV, thus a limited amount of information can be published; 2) there is a time-lag between up-to-date business and relevant public knowledge; 3) the results are sensitive or confidential. A case study allows researchers the access to previously unavailable or unpublished data. It also acts as a powerful tool to analyze complex phenomena that are too difficult to explain with surveys or experimental methods (Baxter and Jack, 2008). In addition to the analysis of archived documents (from PMV, municipal, provincial and federal governments, consulting firms, non-profit organizations and so on), seven semi-structured, in-depth interviews (six in-person interviews and one phone interview) with scholars, industrial professionals affiliated with PMV and the Fraser Basin Council, were conducted in the early 2016. The purpose of these interviews was to 1) validate findings from archived documents; 2) get access to comprehensive and current materials about adaptation; 3) enhance our understanding of the current situation at PMV and obtain the input and ideas from the front-line staffs.

Interviews are widely employed in case studies, for it enables researchers to communicate with the ‘right’ people and obtain ‘inside’ knowledge of their operations and experiences. The interviewees were selected by adopting the ‘Snowball sampling’ techniques. The author started from professionals in charge of climate change adaptation at PMV and asked them to recommend potential interviewees that they deem the most relevant to the research. This technique helps to include the ‘right’ people to share their knowledge, perceptions, and experience. Consequently, data from a limited number of interviews within project constraints can be regarded as sufficient and reliable. In total, four interviewees were from PMV, whose responsibilities include climate change adaptation or general environmental issues (notably sustainability development). Two interviewees were from the Fraser Basin Council, a non-profit organization dedicated to collaborating and coordinating issues on the Fraser River to advance sustainable development. The Fraser Basin Council acts as a coordinator and communication facilitator in an inter-jurisdictional adaptation project, a program in which PMV is currently a participant. Also, according to the interviewees from PMV, this project is their main adaptation effort. Therefore, interviews with staffs working on the regional project at Fraser Basin Council are an indispensable part of the case study. The last interviewee is a distinguished scholar, whose research interest is climate change and port adaptation.

The job domain of the interviewees ranges from project managers to engineers, from specialists dedicated to climate change to general environmental managers. The average duration of interviews ranged from one hour to two hours. Main interview questions include what top climate change risks they are facing, how they prioritize risks, current adaptation efforts, adaptation planning process, obstacles in the process of adaptation, and their solutions. Specifically, the interview covered the following issues[3]:

1) Located on the western coast of Canada, your port attempts to protect its assets against the potential impacts of climate change, which is referred to adaptation efforts to climate change risks. In your opinion, does the planning approach of adaptation differ from others? Why do you think so? Does it follow a top-down design or a bottom-up approach? Do you believe the existing approach of adaptation planning works well? Can you explain why? If not, what method do you think should be adopted for the effectiveness of adaptation planning?
2) What do you think are the primary (say, top 3) climate change risks faced by your port? What impacts (regarding frequency, severity of consequences) have they brought to your port during the last decade? Is there any adaptation action to address the problem caused by climate change? If yes, what are they, which climate change risks have you addressed and how do they work?
3) What principles does your port follow to prioritize identified climate change risks? In other words, how do your port determine the top issues (the most urgent

[3] These questions were prepared for PMV. Questions for Fraser Basin Council were modified accordingly (for example, change ‘port’ to ‘council’).

and pressing risks that need immediate actions)? Why do you believe these principles help you to sort out priorities reasonably? In your opinion, is the ranking affected by the amount of knowledge that the port has on a particular climate change risk? For example, if the port is struck by storms annually, thus knowledgeable with storm forecast and the associated losses, while, it is not familiar with impacts of sea level rise, then it is more likely for the port to prioritize storms over sea level rise.

4) Do you think your port's adaptation plan is an 'action plan', which involves assessment of the current situation, identification of climate change risks, prioritization of these issues, design and implementation of adaptation plans and evaluation of adaptation actions? That is to say, it is not a study paper of current conditions, but a plan with 'real actions'?
5) Overall, from design to implementation and evaluation, in your opinion, on which stage have you met the most difficulties? Or put in another way, on which stage do you find it is the hardest to process further? Why do you think so? What have you done to deal with the problems? Also, what do you think should be done to solve the problem?

The order of these questions (see Appendix B for all interview questions) was not strictly followed, depending on interviewee's answers. Also, information was re-examined and verified using the answers acquired from different participants. This enhanced both the validity and reliability of their responses. Transcripts based on all notes and data from the interviews were completed within 24 hours after each interview was performed.

CHAPTER 4: SURVEY RESULT

4.1 Analysis of survey result

4.1.1 Statistical analysis

Existing risks and impacts due to climate change

To measure climate change impacts over the past five years, parameters ‘frequency’ and ‘severity of consequences’ were utilized. Each of the parameters was scaled to five levels (1-5). Generally, more than half of the respondents agreed that SLR impacts did not happen or only happened once over the past five years. Among the five SLR impacts as illustrated in Figure 4.1, deposition and sedimentation along port/terminal’s channels are the most common, with 61% of the respondents (41 out of 67) reporting that it has happened at least once, followed by coastal erosion at or adjacent to the port/terminal (51%, 34 out of 67). In terms of frequency, these participants hold the view that transport infra- and superstructures and utilities are the most unlikely to be damaged by SLR, as only 33% reported that this impact has taken place at least once. In the ‘I don't know/I’m not sure’ category, approximately 10% of the respondents have no knowledge of the SLR impact frequency. This could be attributed to the fact that no records exist or that they are simply unaware of them.

Figure 4.1. Participants reporting different frequencies of the five impacts posed by SLR over the past five years

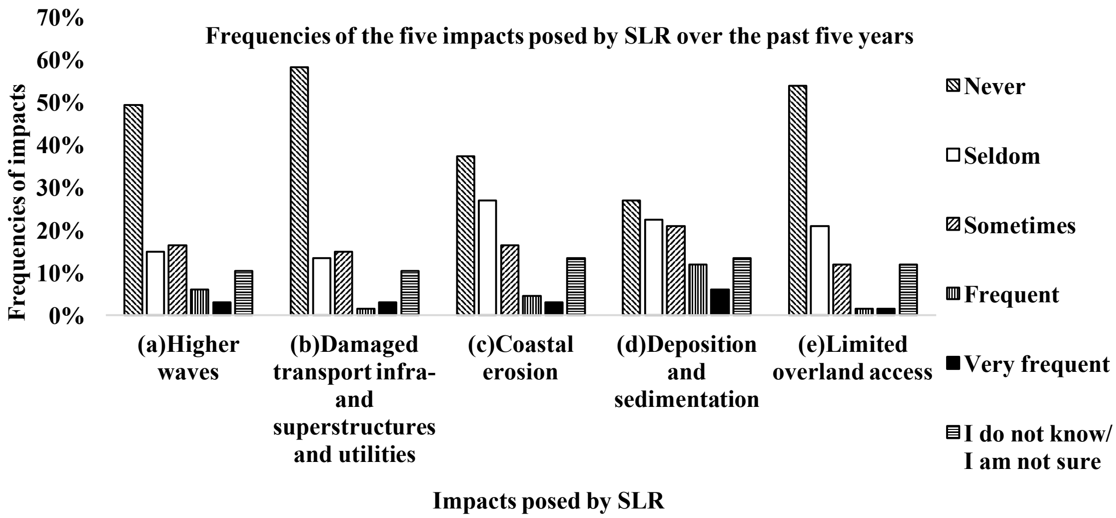
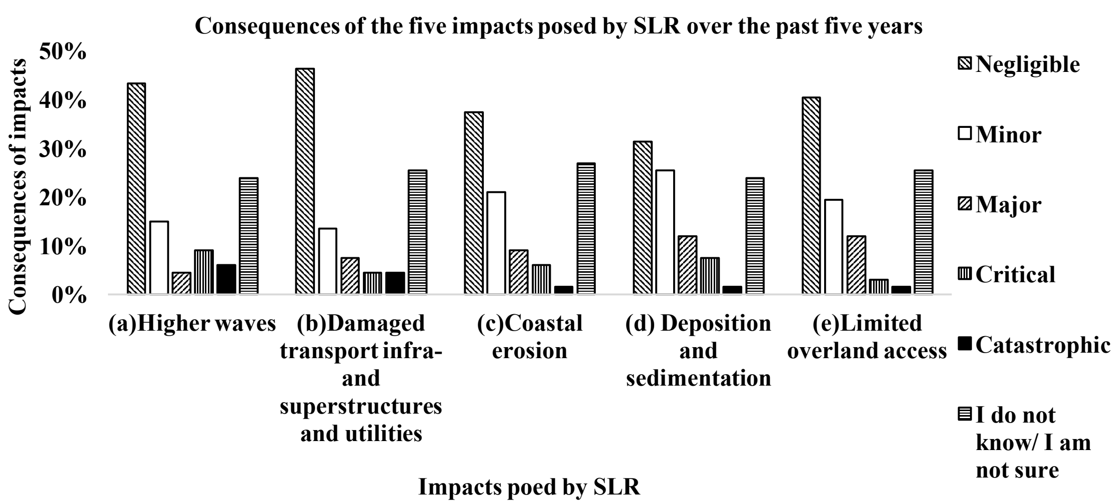


Figure 4.2. Participants reporting different consequences of the five impacts posed by SLR over the past five years



Note[4]*:* (a) SLR resulted in higher waves that damaged your port/terminal's facilities and/or ships berthed alongside. (b) Transport infra- and superstructures (like cranes and warehouses) and utilities in your port/terminal were flooded or damaged because of SLR. (c) Coastal erosion occurred at or adjacent to your port/terminal. (d) Deposition and sedimentation occurred along your port/terminal's channels. (e) Overland access (road, railway) to your port/terminal was limited due to more incidents of flooding.

[4] The note refers to Figure 4.1 and Figure 4.2.

Regarding the severity of consequences, the most serious impact of SLR to ports is still deposition and sedimentation, with 46% of the participants reporting SLR resulted in minor damages to their ports. Damage caused by SLR to transport infra- and superstructures had the least impact, with 31 respondents selecting the negligible category. Hence, same with the frequency part, damaged transport infra- and superstructures as well as utilities are the last loss that should be considered. Approximately 25% of the participants reported that they did not have any or very limited knowledge of the severity of consequences. The percentage of ‘I don't know/I’m not sure’ is second only to the negligible level. Overall, deposition and sedimentation were thought to be the most serious impacts caused by SLR on ports.

47 respondents (70%) claimed that there had been downtime at least once in the past five years, making it the most prevalent of the four high winds and storms’ impacts (Figure 4.3). Almost half of the participants indicated that the other three impacts had taken place at least once (52% for waves, 51% for damaged transport infra- and superstructures and utilities, and 52% for limited overland access). Compared to SLR, it is clear that participants have a better knowledge of impacts (less than 10%) caused by high winds and/or storms regarding frequency.

Figure 4.3. Participants reporting different frequencies of the four impacts posed by high winds and/or storms over the past five years

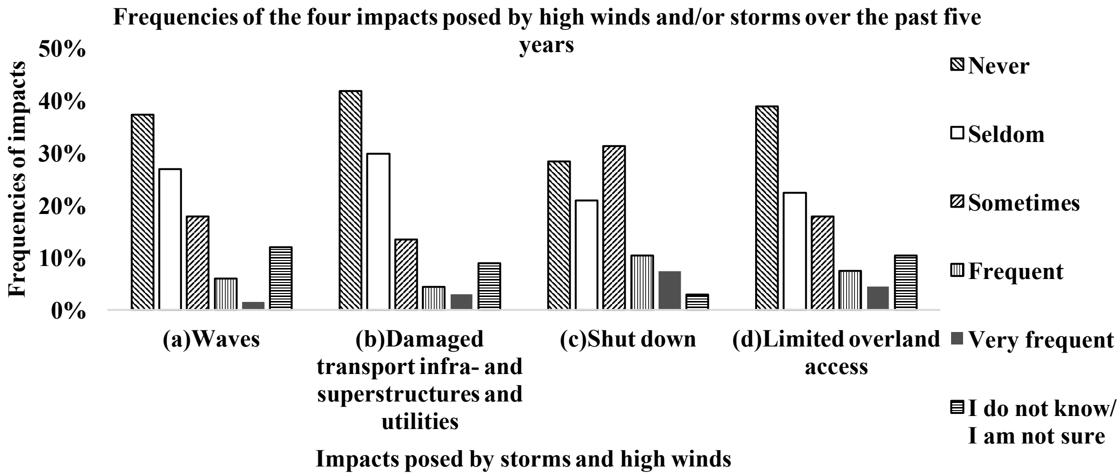
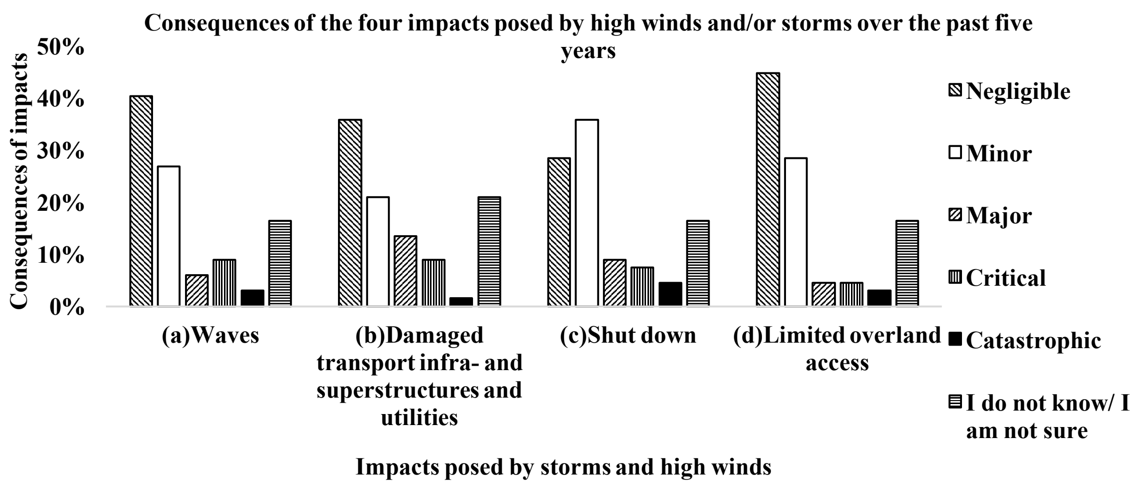


Figure 4.4. Participants reporting different consequences of the four impacts posed by high winds and/or storms over the past five years



Note[5]*:* (a) Waves due to stronger storms damaged port/terminal facilities and/or ships berthed alongside; (b) Transport infra- and superstructures (e.g., cranes and warehouses) and/or utilities in the port/terminal were flooded or damaged due to higher winds and/or storms; (c) Your port/terminal operation was shut down due to higher winds and/or storms; (d) Overland access (road, railway) to your port/terminal was limited due to higher winds and/or storms.

[5] The note refers to Figure 4.3 and Figure 4.4.

Shut down is also the most prevalent impact, with 57% of the respondents reporting that it had at least caused ‘minor’ damage to ports. Approximately 18% of the participants had no idea about the severity of consequences (lower than that of SLR (25%)). In conclusion, port decision-makers seem to have greater knowledge of impacts caused by high winds and/or storms than those brought by SLR. Their perceptions about frequency are clearer than those about consequences.

Recent adaptation measures to climate change risks

In response to the question of how ports address climate change operational risk, the results among the participants were quite variable. 33% (the largest portion) claimed that climate change had not currently been addressed while 25% indicated that it had been addressed as part of port design guidelines or standards. More detailed structures such as specific climate change planning document, port/terminal’s insurance, in port/terminal’s budget came in at 21%, 10% and 13%, respectively (Figure 4.5). These results suggest that adaptation strategies and actions had only minimally been addressed.

In terms of specific protective measures (Figure 4.6), it can be concluded that port/terminal authorities are aware of protection measures, such as breakwater (33%), storm response plan (28%), storm insurance (24%) and protective dike (24%). 33% of the participants were expecting plans to replace/ upgrade existing structures. The results suggest that ports/terminal decision-makers have been implementing strategies and actions based on issues and concerns specific to their needs. 15% of the respondents indicated that they were not aware of any protective measures implemented at their ports.

In general, ports adaptation plans and subsequent implementations of these plans seem unsystematic. Adaptation strategies are still being developed. Ports are still figuring out how frequent and serious the impacts can be, how to plan adaptation measures, on which strategic level these plans ought to be, and which protective measures they can effectively and efficiently take.

Figure 4.5. Adaptation strategies and specific actions to build resilience at ports

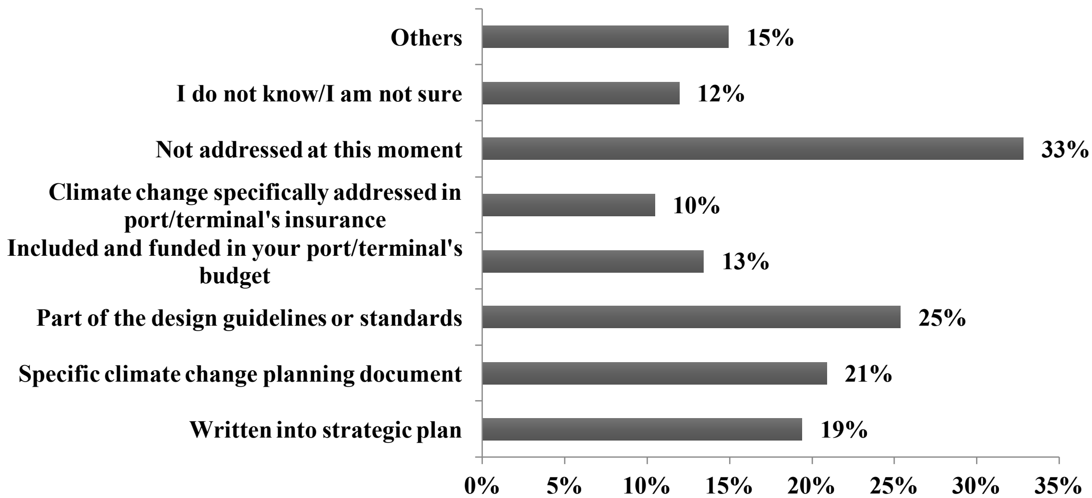
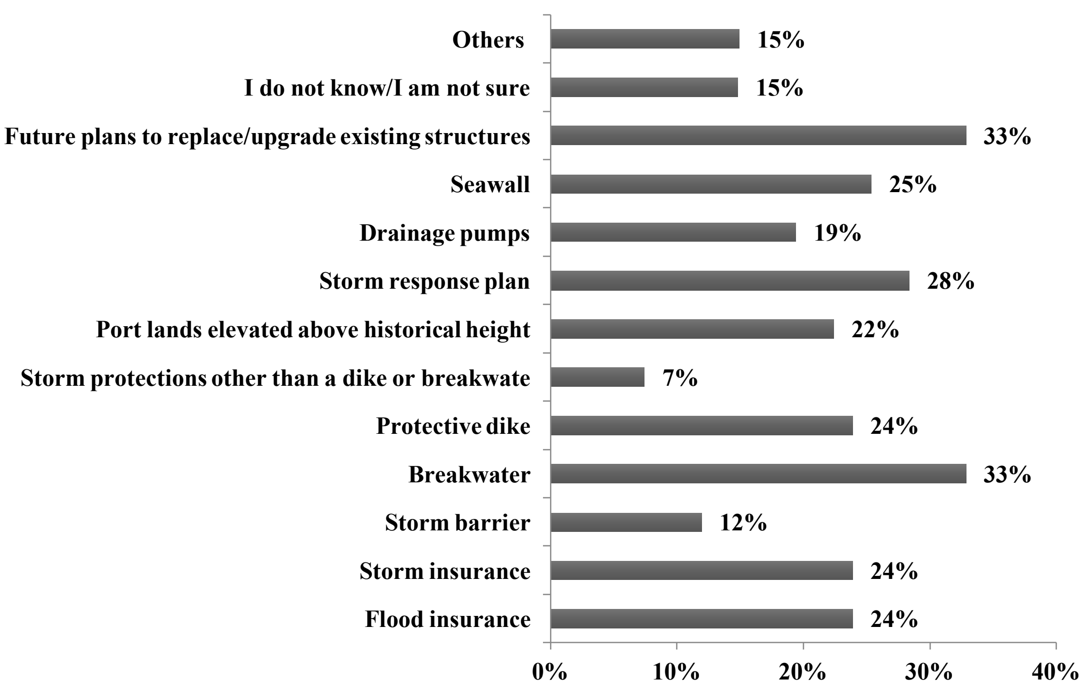


Figure 4.6. Protective measures for adaptive responses to climate change at ports



4.1.2 Hypothesis testing

H_1: If there is no adaptation measure undertaken in the near future, climate change will pose more serious impacts to ports.

A sign test was applied for hypothesis testing. Figure 4.7 is an example of the output. The two-sided test examined the difference between two pairs of observations and the results are neutral indicators. The p-value of the two-sided test in Figure 4.7 is 0, less than 0.05; therefore, the null hypothesis (H_0) was rejected, accepting the alternative one. That is to say, the severity of consequences of higher waves caused by SLR is significantly different between the past five years and the future without adaptation. The one-sided test provided indictors of positive and negative results. The p-value of the 'negative' test is 0, under the significance level, thus suggesting the impacts of higher waves posed by climate change were believed to cause more loss in the future. The p-values of all the two-sided tests and 'negative' one-sided tests are less than 0.05, indicating no matter SLR or high winds & storms, port decision-makers believed that these risks would pose more serious loss to ports. H_1 is accepted.

Figure 4.7. An example of Stata output of the hypothesis testing between the past and the future scenarios

```
. signtest slr_a_soc_past= slr_a_soc_fth

Sign test

        sign │    observed    expected
─────────────┼────────────────────────
    positive │           5          17
    negative │          29          17
        zero │          18          18
─────────────┼────────────────────────
         all │          52          52

One-sided tests:
  Ho: median of slr_a_s~st - slr_a_soc_fth = 0 vs.
  Ha: median of slr_a_s~st - slr_a_soc_fth > 0
      Pr(#positive >= 5) =
         Binomial(n = 34, x >= 5, p = 0.5) =  1.0000

  Ho: median of slr_a_s~st - slr_a_soc_fth = 0 vs.
  Ha: median of slr_a_s~st - slr_a_soc_fth < 0
      Pr(#negative >= 29) =
         Binomial(n = 34, x >= 29, p = 0.5) =  0.0000

Two-sided test:
  Ho: median of slr_a_s~st - slr_a_soc_fth = 0 vs.
  Ha: median of slr_a_s~st - slr_a_soc_fth != 0
      Pr(#positive >= 29 or #negative >= 29) =
         min(1, 2*Binomial(n = 34, x >= 29, p = 0.5)) =  0.0000
```

H_2: Adaptation measures will be effective in enhancing the resilience of port facilities and infrastructure.

The same method was adopted to test the second hypothesis (see an example in Figure 4.8). The sign test was conducted 21 times regarding SLR, as seven adaptation measures were designed to address five impacts and each adaptation measure had three parameters (timeframe, severity of consequence, and likelihood). Each sign test output three p-values, two for the one-sided tests and the third one for the two-sided test. However, only 6 out of the 63 statistical indicators are less than 0.05. Except for one p-value from a two-sided test which indicated a neutral result, the other five significant results are from 'slr_c_prob', 'slr_d_time', 'slr_d_soc', 'slr_d_prob', and 'slr_e_2_prob'. Interestingly, all the five one-sided tests provide 'negative' results, as illustrated in Table 4.1. The p-value of ‘slr_d_time’ suggests that deposition and sedimentation caused by SLR will occur sooner without future adaptation measures. On the contrary, the remaining four statistically significant results indicate that impacts can be even worse with adaptation measures in the future.

Figure 4.8. An example of Stata output of the hypothesis testing between the two future scenarios

```
. signtest slr_a_time_without= slr_a_time_with

Sign test

        sign |    observed    expected
-------------+------------------------
    positive |          11        12.5
    negative |          14        12.5
        zero |          43          43
-------------+------------------------
         all |          68          68

One-sided tests:
  Ho: median of slr_a_ti~t - slr_a_time_with = 0 vs.
  Ha: median of slr_a_ti~t - slr_a_time_with > 0
      Pr(#positive >= 11) =
         Binomial(n = 25, x >= 11, p = 0.5) =  0.7878

  Ho: median of slr_a_ti~t - slr_a_time_with = 0 vs.
  Ha: median of slr_a_ti~t - slr_a_time_with < 0
      Pr(#negative >= 14) =
         Binomial(n = 25, x >= 14, p = 0.5) =  0.3450

Two-sided test:
  Ho: median of slr_a_ti~t - slr_a_time_with = 0 vs.
  Ha: median of slr_a_ti~t - slr_a_time_with != 0
      Pr(#positive >= 14 or #negative >= 14) =
         min(1, 2*Binomial(n = 25, x >= 14, p = 0.5)) =  0.6900
```

Table 4.1. Sign test results of the future with and without adaptation measures regarding SLR

ADAPTATION	PARAMETER	POSITIVE_ ONE SIDED	NEGATIVE_ ONE SIDED	DIFFERENT_ TWO SIDED
	slr_a_time	0.7878	0.345	0.69
slr_a	slr_a_soc	0.9552	0.0877	0.1755
	slr_a_prob	0.7566	0.3642	0.7283
	slr_b_1_time	0.779	0.3506	0.7011
slr_b_1	slr_b_1_soc	0.779	0.3506	0.7011
	slr_b_1_prob	0.655	0.5	1
	slr_b_2_time	0.9449	0.1077	0.2153
slr_b_2	slr_b_2_soc	0.7709	0.3555	0.7111
	slr_b_2_prob	0.5	0.655	1
	slr_c_time	0.8761	0.221	0.4421
slr_c	slr_c_soc	0.9599	0.0814	0.1628
	slr_c_prob	0.9947	**0.0173**	**0.0347**
	slr_d_time	0.9853	**0.0354**	0.0708
slr_d	slr_d_soc	0.9904	**0.0261**	0.0522
	slr_d_prob	0.9825	**0.0401**	0.0801
	slr_e_1_time	0.8275	0.2858	0.5716
slr_e_1	slr_e_1_soc	0.8852	0.2122	0.4244
	slr_e_1_prob	0.5806	0.5806	1
	slr_e_2_time	0.8595	0.2366	0.4731
slr_e_2	slr_e_2_soc	0.9786	**0.0494**	0.0987
	slr_e_2_prob	0.655	0.5	1

Note: 1) A/b/c/d/e from slr_a/b/c/d/e is the impact caused SLR. 2) A/b_1/b_2/c/d/e_1/e_2 from slr_ a/b_1/b_2/c/d/e_1/e_2_time/soc/prob is the specific adaptation measure. A is to build new breakwaters and/or increase their dimensions; b_1 is to improve transport infra- and superstructures resilience to flooding; b_2 is to elevate port land; c is to protect coastline and increase beach nourishment programs; d is to increase and/or expand dredging; e_1 is to improve quality of land connections to port/terminal; e_2 is to diversify land connections to port/terminal. 3) Prob, time, soc are likelihood, timeframe, and severity of consequence, respectively.

Turning to the high winds and storms, five adaptation measures were designed to address the four impacts. 15 comparisons were tested regarding three parameters (timeframe, severity of consequence, and likelihood). Each comparison has three p-values and among all the 45 indicators, 10 p-values are statistically significant, as shown in Table 4.2.

Table 4.2. Sign test results of the future with and without adaptation measures regarding high winds and storms

ADAPTATION	PARAMETER	POSITIVE_ ONE SIDED	NEGATIVE_ ONE SIDED	DIFFERENT_ TWO SIDED
hw_a	hw_a_time	0.9962	**0.01**	**0.0201**
	hw_a_soc	0.8192	0.2923	0.5847
	hw_a_prob	0.1808	0.8998	0.3616
hw_b	hw_b_time	0.9996	**0.0017**	**0.0033**
	hw_b_soc	0.9622	0.0843	0.1686
	hw_b_prob	0.5775	0.5775	1
hw_c	hw_c_time	0.9993	**0.0022**	**0.0043**
	hw_c_soc	0.9461	0.1148	0.2295
	hw_c_prob	0.1002	0.9506	0.2005
hw_d_1	$hw\_d_1\_time$	0.9999	**0.0005**	**0.0009**
	$hw\_d_1\_soc$	0.9646	0.0748	0.1496
	$hw\_d_1\_prob$	0.1725	0.9075	0.3449
hw_d_2	$hw\_d_2\_time$	1	**0.0001**	**0.0003**
	$hw\_d_2\_soc$	0.8998	0.1808	0.3616
	$hw\_d_2\_prob$	0.221	0.8761	0.4421

Note: 1) HW stands for high winds and storms. 2) A/b/c/d from hw_a/b/c/d is the impact caused high winds and storms. 3) $A/b/c/d_1/d_2$ from $hw\_ a/b/c/d_1/d_2\_time/soc/prob$ is the specific adaptation measure. A is to build new breakwaters and/or increase their dimensions; b is to improve transport infra- and superstructures resilience to flooding; c is to improve management to prevent effects; d_1 is to improve quality of land connections to port/terminal; d_2 is to diversify land connections to port/terminal. 4) Prob, time, soc present likelihood, timeframe, and severity of consequence, respectively.

All of the significant results fall into the category of ‘timeframe’. The significant p-values of the ‘negative’ one-sided tests indicate that adaptation measures will effectively postpone the first occurrence of their associated climate change impacts. In general, it can be concluded that adaptation to climate change is believed to 1) have no effect; 2) have positive effects; and 3) even have negative effects. Hence, H_2 is partially accepted.

Verification of hypothesis testing

A Friedman test (see an example in Figure 4.9) was conducted to verify the results of the hypothesis testing. The Friedman test is a non-parametric test to examine the difference among multiple groups when the measurement of the dependent variable is in ordinal format (Sheldon et al., 1996). Taken consistency of the three scenarios (the past, the future without adaptation and the future with adaptation) into consideration, the severity of consequence was selected as the tested variable using SPSS (version 22). With all of the p-values (as illustrated in the left halves of Table 4.3 and 4.4) are less than 5%, the null hypothesis that the three groups of data are from the same distribution was rejected. Consequently, the results of the Friedman test indicate that consequences of impacts posed by climate change in the three scenarios are significantly different. However, the Friedman test could not reveal which of the groups should be responsible for the difference.

Figure 4.9. An output example of the Friedman test

Friedman Test

Ranks

	Mean Rank
slr_a_soc_past	1.52
slr_a_soc_without	2.15
slr_a_soc_with	2.33

Test Statistics[a]

N	52
Chi-Square	27.745
df	2
Asymp. Sig.	.000

a. Friedman Test

Figure 4.10. An output example of the Post Hoc test

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
slr_a_soc_without - slr_a_soc_past	Negative Ranks	5[a]	13.00	65.00
	Positive Ranks	29[b]	18.28	530.00
	Ties	18[c]		
	Total	52		

a. slr_a_soc_without < slr_a_soc_past

b. slr_a_soc_without > slr_a_soc_past

c. slr_a_soc_without = slr_a_soc_past

Test Statistics[a]

	slr_a_soc_without - slr_a_soc_past
Z	-4.189[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

A Wilcoxon signed-rank test was then conducted as the Post Hoc test to determine the relationships between each two groups. The significance level was adjusted to 0.017 based on the rule of Bonferroni correction. As can be seen in the right halves of Table 4.3 and 4.4, there is a significant difference between the past and the future without adaptation measures. Hence, the impacts of climate change would move further to be more serious without future adaptation actions. Conversely, an apparent benefit of adaptation measures in the consequence of climate change impacts in the future ($p \geq 0.017$) could not be identified. Taken together, these results suggest the findings of the above hypothesis testing are robust. Next section moves to investigate the difference among different regions.

Table 4.3. Friedman test and post hoc test results of impacts caused by SLR in terms of severity of consequences

SLR_PARAMETER	FRIEDMAN TEST	PAIR COMPARISON	POST HOC TEST
		past_without	**0.000**
slr_a_soc	**0.000**	past_with	**0.000**
		with_without	0.286
		past_without	**0.000**
slr_b_1_soc	**0.000**	past_with	**0.000**
		with_without	0.950
		past_without	**0.000**
slr_b_2_soc	**0.000**	past_with	**0.000**
		with_without	0.462
		past_without	**0.002**
slr_c_soc	**0.000**	past_with	**0.000**
		with_without	0.188
		past_without	**0.002**
slr_d_soc	**0.000**	past_with	**0.000**
		with_without	0.068
		past_without	**0.000**
slr_e_1_soc	**0.000**	past_with	**0.001**
		with_without	0.528
		past_without	**0.000**
slr_e_2_soc	**0.000**	past_with	**0.000**
		with_without	0.125

Note: 1) Past_without is the comparison between data from the past five years and future without adaptation measures. 2) Past_with is the comparison between data from the previous five years and future with adaptation measures. 3) With_without is the comparison between data from the future without adaptation measures and future with adaptation measures. 4) Soc is severity of consequence. 5) A is to build new breakwaters and/or increase their dimensions; b_1 is to improve transport infra- and superstructures resilience to flooding; b_2 is elevation of port land; c is to protect coastline and increase beach nourishment programs; d is to increase and/or expand dredging; e_1 is to improve quality of land connections to port/terminal; e_2 is to diversify land connections to port/terminal.

Table 4.4. Friedman test and post hoc test results of impact caused by high winds and/or storms in terms of severity of consequences

HW_PARAMETER	FRIEDMAN TEST	PAIR COMPARISON	POST HOC TEST
hw_a_soc	**0.000**	past_without	**0.000**
		past_with	**0.000**
		with_without	0.445
hw_b_soc	**0.000**	past_without	**0.002**
		past_with	**0.000**
		with_without	0.048
hw_c_soc	**0.000**	past_without	**0.005**
		past_with	**0.000**
		with_without	0.051
hw_d_1_soc	**0.000**	past_without	**0.000**
		past_with	**0.000**
		with_without	0.045
hw_d_2_soc	**0.000**	past_without	**0.000**
		past_with	**0.000**
		with_without	0.214

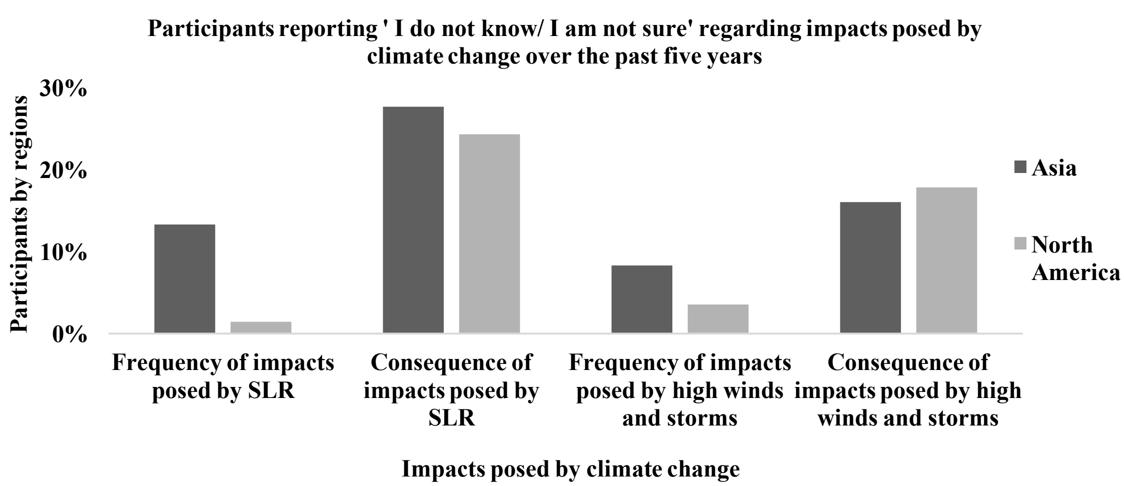
Note: 1) Past_without is the comparison between data from the past five years and future without adaptation measures. 2) Past_with is the comparison between data from the past five years and future with adaptation measures. 3) With_without is the comparison between data from the future without adaptation measures and future with adaptation measures. 4) Soc is severity of consequence. 5) A is to build new breakwaters and/or increase their dimensions; b is to improve transport infra- and superstructures resilience to flooding; c is to improve management to prevent effects; d_1 is to improve quality of land connections to port/terminal; d_2 is to diversify land connections to port/terminal.

4.1.3 Regional analysis

Knowledge about climate change impacts

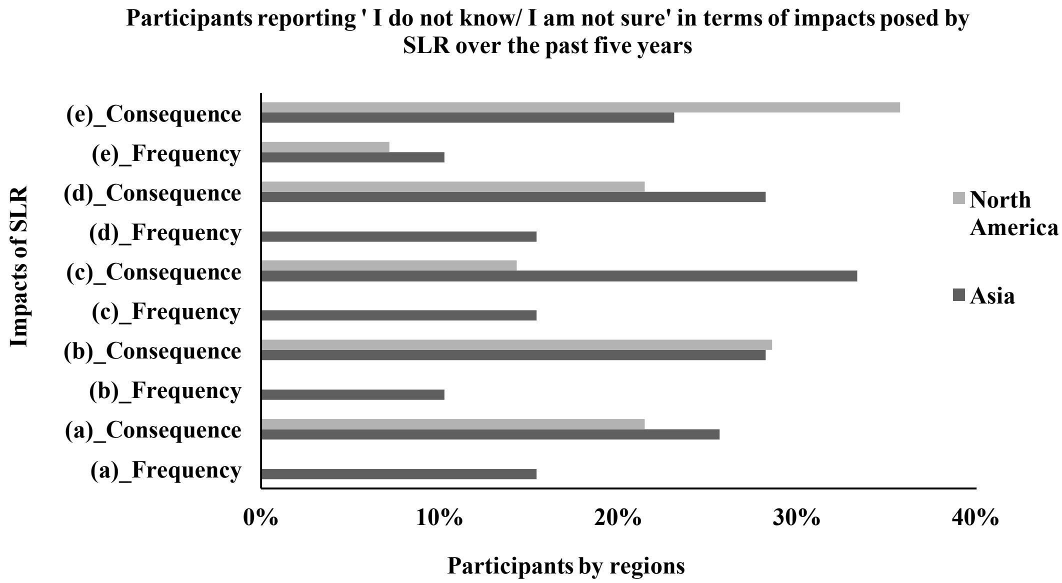
Data of Asia (n=39) and North America (n=14), the two largest portions of the valid responses, were tested to examine the regional difference in the knowledge of climate change impacts. The dataset of ‘I don't know/ I have no idea’ was analyzed so as to assess the respondents’ knowledge of climate change impacts. Figure 4.11 provides an overview of respondents reporting their incompetency to estimate the impacts of climate change. Participants from North America reported lower percentages in response to this item in three variables (frequency and severity of consequence of impacts caused by SLR as well as frequency of impacts posed by high winds and/ or storms). Taken together, these results indicate that participants from North America have more knowledge of impacts posed by climate change. This regional difference mainly falls into the category of frequency of climate change impacts. Interestingly, decision-makers of Asian ports, on the whole, demonstrated to be more conversant with high winds/ storm- related impacts than effects posed by SLR. The respondents from North America, on the other hand, were not detected to have such tendency. Turning now to the results regarding the two parameters, percentages in frequency are lower than those in severity of consequence no matter for which climate change risk. It is apparent that respondents find it more challenging to report information in effect estimation.

Figure 4.11. Average percentage of participants divided by regions reporting ' I do not know/ I am not sure' regarding impacts posed by climate change over the past five years



The results of knowledge level regarding SLR are presented in Figure 4.12. This figure is quite revealing in several ways. First, there is a clear trend of more knowledge of frequency than the severity of consequence. Second, except for the consequence of limited overland access caused by SLR, on average, the participants from North America indicated that they had more knowledge of impacts posed by SLR than the Asian port decision-makers. One striking observation to emerge from the data comparison was that the respondents from North America tend to be the most experienced with the impact of coastal erosion, whereas Asian participants had a precisely opposite trend. Interestingly, limited overland access, the impact with the largest percentage of respondents in North America, is the most familiar impact to Asian participants.

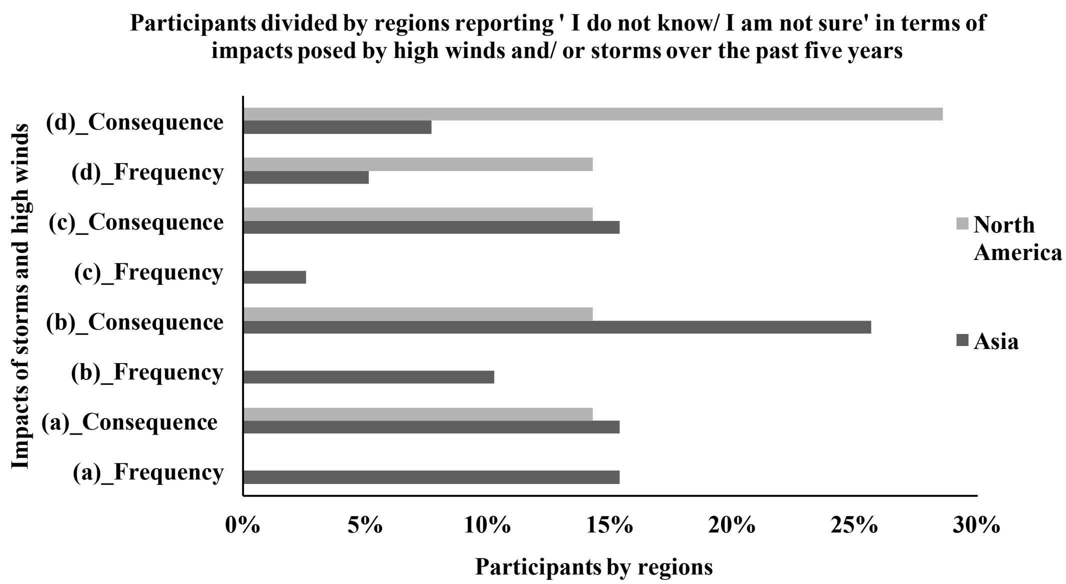
Figure 4.12. Participants divided by regions reporting ' I do not know/ I am not sure' in terms of impacts posed by SLR over the past five years



Note: (a) SLR resulted in higher waves that damaged your port/terminal's facilities and/or ships berthed alongside. (b) Transport infra- and superstructures (like cranes and warehouses) and utilities in your port/terminal were flooded or damaged because of SLR. (c) Coastal erosion occurred at or adjacent to your port/terminal. (d) Deposition and sedimentation occurred along your port/terminal's channels. (e) Overland access (road, railway) to your port/terminal was limited due to more incidents of flooding.

The Figure 4.13 also reveals that respondents have a better knowledge regarding the frequency of the impacts posed by high winds and/or storms than consequences. Decision-makers in North America were shown to have a better general knowledge of climate change impacts. They were more familiar with the impacts ‘higher waves’, ‘damaged transport infra- and superstructures and utilities’ as well as ‘downtime’, whereas Asian respondents had more knowledge of the impact ‘limited overland access’. The biggest difference between the two regions falls into the impact of ‘damaged transport infra- and superstructure and utilities’. The respondents reported similar situations regarding the impact of ‘downtime’. However, a significant gap in the knowledge of 'limited overland access' impact was detected for decision-makers in ports located in North America.

Figure 4.13. Participants divided by regions reporting ' I do not know/ I am not sure' in terms of impacts posed by high winds and/ or storms over the past five years



Note: (a) Waves due to stronger storms damaged port/terminal facilities and/or ships berthed alongside; (b) Transport infra- and superstructures (e.g., cranes and warehouses) and/or utilities in the port/terminal were flooded or damaged due to higher winds and/or storms; (c) Your port/terminal operation was shut down due to higher winds and/or storms; (d) Overland access (road, railway) to your port/terminal was limited due to higher winds and/or storms.

Effectiveness of adaptation measures

Further statistical tests were performed to investigate whether adaptation measures were deemed effective in the future. A sign test was conducted to examine the difference between regional data from Asia and North America. The following tables (Table 4.5 and Table 4.6) show the statistical results of Asian ports. In general, adaptation measures were predicted not to affect impacts of SLR in the foreseeable future. Interestingly, the severity of consequence regarding the impacts ‘higher waves’ and ‘limited overland access’ were reported to be even more serious with adaptation measures. A clear benefit of adaptation measures in the mediation of impacts posed by high winds and/or storms regarding timeframe could be identified (except for the adaptation action to tackle the impact ‘higher waves’). However, no significant differences were found between the future scenarios with and without adaptation regarding the severity of consequence and likelihood of climate change impacts.

Table 4.5. Sign test results of the future with and without adaptation in terms of SLR in Asian ports

ADAPTATION	PARAMETER	POSITIVE_ ONE SIDED	NEGATIVE_ ONE SIDED	DIFFERENT_ TWO SIDED
	slr_a_time	0.8491	0.3036	0.6072
slr_a	slr_a_soc	0.9904	**0.0318**	0.0636
	slr_a_prob	0.9423	0.1316	0.2632
	slr_b_1_time	0.6855	0.5000	1.0000
slr_b_1	slr_b_1_soc	0.8491	0.3036	0.6072
	slr_b_1_prob	0.6964	0.5000	1.0000
	slr_b_2_time	0.8204	0.3238	0.6476
slr_b_2	slr_b_2_soc	0.8491	0.3036	0.6072
	slr_b_2_prob	0.5000	0.6964	1.0000
	slr_c_time	0.9824	0.0592	0.1185
slr_c	slr_c_soc	0.9793	0.0577	0.1153
	slr_c_prob	0.9270	0.1938	0.3877
	slr_d_time	0.8949	0.2272	0.4545
slr_d	slr_d_soc	0.9993	**0.0038**	**0.0075**
	slr_d_prob	0.9423	0.1316	0.2632
	slr_e_1_time	0.8338	0.3145	0.6291
slr_e_1	slr_e_1_soc	0.6128	0.6128	1.0000
	slr_e_1_prob	0.2120	0.9102	0.4240
	slr_e_2_time	0.6855	0.5000	1.0000
slr_e_2	slr_e_2_soc	0.6964	0.5000	1.0000
	slr_e_2_prob	0.4018	0.7728	0.8036

Note: 1) Time is timeframe. 2) Soc is severity of consequence. 3) Prob is likelihood. 4) A is to build new breakwaters and/or increase their dimensions; b_1 is to improve transport infra- and superstructures resilience to flooding; b_2 is to elevate port land; c is to protect coastline and increase beach nourishment programs; d is to increase and/or expand dredging; e_1 is to improve quality of land connections to port/terminal; e_2 is to diversify land connections to port/terminal.

Table 4.6. Sign test results of the future with and without adaptation in terms of high winds and storms in Asian ports

ADAPTATION	PARAMETER	POSITIVE_ ONE SIDED	NEGATIVE_ ONE SIDED	DIFFERENT_ TWO SIDED
hw_a	hw_a_time	0.9534	0.1050	0.2100
	hw_a_soc	0.9713	0.0898	0.1796
	hw_a_prob	0.8204	0.3238	0.6476
hw_b	hw_b_time	0.9962	**0.0154**	**0.0309**
	hw_b_soc	0.9539	0.1334	0.2668
	hw_b_prob	0.8338	0.3145	0.6291
hw_c	hw_c_time	0.9967	**0.0113**	**0.0227**
	hw_c_soc	0.9824	0.0592	0.1185
	hw_c_prob	0.3238	0.8204	0.6476
hw_d_1	hw_d_1_time	0.9995	**0.0020**	**0.0041**
	hw_d_1_soc	0.6762	0.5000	1.0000
	hw_d_1_prob	0.6855	0.5000	1.0000
hw_d_2	hw_d_2_time	0.9993	**0.0036**	**0.0072**
	hw_d_2_soc	0.6855	0.5000	1.0000
	hw_d_2_prob	0.5000	0.6855	1.0000

Note: 1) Time is timeframe. 2) Soc is severity of consequence. 3) Prob is likelihood. 4) A is to build new breakwaters and/or increase their dimensions; b is to improve transport infra- and superstructures resilience to flooding; c is to improve management to prevent effects; d_1 is to improve quality of land connections to port/terminal; d_2 is to diversify land connections to port/terminal.

Admittedly, the sample size of North America may be insufficient to provide a highly robust result. However, this sample size (n=14) is regarded as a reasonable number to conduct a rough experiment in the sign test (Dixon and Mood, 1946). As illustrated in Table 4.7, the sign test did not show any significant differences between the future scenarios with and without adaptation measures regarding SLR. Similarly, only trace amounts of p-values (two p-values of the 45 indicators in Table 4.8) were detected as below the significance level, suggesting that adaptation measure would be beneficial to mediate the impacts posed by high winds and/ or storms. The participants believed that new or extended breakwaters would effectively decrease the probability of damage associated with higher waves. The measure 'improvement in management to prevent effects' was expected to postpone the timeframe of the first observation of port's downtime due to higher winds and/ or storms.

Table 4.7. Sign test results of the future with and without adaptation in terms of SLR in North America[6]

ADAPTATION	PARAMETER	POSITIVE_ ONE SIDED	NEGATIVE_ ONE SIDED	DIFFERENT_ TWO SIDED
slr_a	slr_a_time	0.8125	0.5000	1.0000
	slr_a_soc	0.7461	0.5000	1.0000
	slr_a_prob	0.9375	0.2266	0.4531
slr_b_1	$slr\_b_1\_time$	0.9844	0.1094	0.2188
	$slr\_b_1\_soc$	0.7461	0.5000	1.0000
	$slr\_b_1\_prob$	0.9375	0.3125	0.6250
slr_b_2	$slr\_b_2\_time$	0.9922	0.0625	0.1250
	$slr\_b_2\_soc$	0.8281	0.3770	0.7539
	$slr\_b_2\_prob$	0.8125	0.5000	1.0000
slr_c	slr_c_time	0.8906	0.3437	0.6875
	slr_c_soc	0.3633	0.8555	0.7266
	slr_c_prob	0.8125	0.5000	1.0000
slr_d	slr_d_time	0.9844	0.1094	0.2188
	slr_d_soc	0.6367	0.6367	1.0000
	slr_d_prob	1.0000	0.0625	0.1250
slr_e_1	$slr\_e_1\_time$	0.8125	0.5000	1.0000
	$slr\_e_1\_soc$	0.9922	0.0625	0.1250
	$slr\_e_1\_prob$	0.6875	0.6875	1.0000
slr_e_2	$slr\_e_2\_time$	0.8906	0.3437	0.6875
	$slr\_e_2\_soc$	0.9805	0.0898	0.1797
	$slr\_e_2\_prob$	0.6875	0.6875	1.0000

[6] Refer to the note of Table 4.5 for detailed descriptions of terms.

Table 4.8. Sign test results of the future with and without adaptation in terms of high winds and storms in North America[7]

ADAPTATION	PARAMETER	POSITIVE_ ONE SIDED	NEGATIVE_ ONE SIDED	DIFFERENT_ TWO SIDED
	hw_a_time	0.9805	0.0898	0.1797
hw_a	hw_a_soc	0.5000	0.7734	1.0000
	hw_a_prob	**0.0312**	1.0000	0.0625
	hw_b_time	0.9648	0.1445	0.2891
hw_b	hw_b_soc	0.8125	0.5000	1.0000
	hw_b_prob	0.6875	0.6875	1.0000
	hw_c_time	0.9961	**0.0352**	0.0703
hw_c	hw_c_soc	0.6562	0.6562	1.0000
	hw_c_prob	0.3125	0.9375	0.6250
	$hw\_d_1\_time$	0.9102	0.2539	0.5078
hw_d_1	$hw\_d_1\_soc$	0.9688	0.1875	0.3750
	$hw\_d_1\_prob$	0.3125	0.9375	0.6250
	$hw\_d_2\_time$	0.9453	0.1719	0.3438
hw_d_2	$hw\_d_2\_soc$	0.8906	0.3437	0.6875
	$hw\_d_2\_prob$	0.1875	0.9688	0.3750

4.2 Discussion and recommendation

This study set out with the aim of assessing the knowledge and perceptions that port decision-makers have towards adaptation measures to climate change impacts. The most obvious finding to emerge from the data analysis in the past scenario is that the respondents had a better knowledge of frequency than consequence. A possible explanation for this result may be the lack of an adequate and robust methodology to measure and calculate the consequences of climate change impacts. It has been challenging to provide an accurate estimation of impacts posed by climate change risks. Simultaneously, such lack in impact analysis can generate obstacles in the

[7] Refer to the note of Table 4.6 for detailed descriptions of terms.

assessment of future scenarios. This finding corroborates the arguments of Moss et al. (2010), who suggested that future scenarios were not decently studied.

The analysis verifies the notion that port decision-makers believe that the impacts posed by SLR and high winds and storms will become more serious (hence, accepting H_1). This conclusion calls for more approaches to address problems posed by climate change, and of course, adaptation is one of the solutions. However, the findings in verifying H_2 suggest a very different, and indeed contradictory, story. There are almost no positive outcomes in SLR (only 1 from 63) as well as severity of consequences and likelihood of high winds and storms. The results reflect respondents' doubts/rather an indifferent attitude on the effectiveness of adaptation measures to climate change. One possible explanation is that they believe that adaptation measures would not take effect, and the other is that they have few concrete ideas on what to do even they are aware of how climate change can potentially impact their ports. Considering the analysis of the current measures, as well as the proportion of 'I do not know/I am not sure', it is more likely that without sufficient reliable data or adequate information, port decision-makers simply do not possess adequate knowledge on the appropriate adaptation measures, and thus struggle to effectively plan their ports to become more resilient to climate change risks.

Analysis of the Asian dataset may reveal the relationship between knowledge and concrete ideas on the effects of adaptation measures. With more exposure to storm events, thus more experience with storm-related impacts, the decision-makers in Asian ports tend to expect effective adaptation measures to postpone the timeframe of the first observation of impacts posed by storms. On the other hand, relatively few knowledge of SLR may be responsible for the trace amounts of significant p-values in Table 4.5. It seems possible that by enhancing the understanding of climate change effects, port decision-makers hold a clearer attitude towards adaptation measures. However, these findings cannot be implemented to all participants, as the above correlation was not found in the case of North America. There are several possible explanations for this result. One might be that port decision-makers in North America were cautious with the definition of effective adaptation actions. Another possible explanation is that the adaptation measures listed in the survey were deemed inappropriate by the participants. Such difference between the two regions, therefore, suggests that the relationship between climate change knowledge and concrete ideas on effective adaptation measures is complex and questionable. With a small sample size, caution must be applied, as the rough findings might not represent the whole region of North America. A further study with more focus on this relationship is therefore suggested.

It seems that port decision-makers lack knowledge on ports' adaptation to climate change risk. Significant results in SLR are comprehensive but dispersed, and all the three parameters are included. Nevertheless, significant p-values only fall in the parameter of timeframe in terms of high winds and storms, and all these p-values in 'timeframe' are significant. This may have a relation to the development of storm and high winds forecast. Port decision-makers may be more confident in forecasting an event time rather than evaluating consequences or the possibility of such event. However, one should note that more than 50% of the survey respondents come from East Asia, and many ports located in this region are suffering from storm attacks (e.g., typhoons) virtually every year. Thus, they may have more historical data for storm forecast. This implies that the 'regional diversification' of climate change impacts is an imperative element in ports adaptation planning. In the regional analysis, no significant p-values in the timeframe of adaptation measures in high winds and storms were found at ports located in North America, whereas the adaptation measures were detected to be effective regarding an event time in Asian ports. Also, the regional analysis in knowledge of climate change impacts indicates that the participants from different regions possess different levels of knowledge regarding various impacts. Among the impacts posed by SLR, decision-makers from Asian ports were the most familiar with the impact 'limited overland access'. Participants from North America conversely tended to have the least knowledge of this impact. It can be argued that local situations must be emphasized during the process of adaptation planning. Especially, nowadays, the best practices are regarded as a popular way to learn about climate change adaptation. It is an effective approach to build appropriate adaptation plans, but it is not necessarily complementary. Indeed, the different results of SLR and high winds and storms raise another potential problem for adaptation planning to climate change. Climate change-related problems are diversified, thus risky to set global benchmarks/milestones to address all the challenges. It is pivotal to tailor-make adaptation methods in accordance with a specific climate change risk.

Another interesting finding in H_2 is that some respondents (as reflected by some p-values) even think that the situation would be better without undertaking any adaptation measures. One reason behind this may be that port decision-makers consider whether the particular adaptation measure is appropriate, as if adaptation measures are taken inappropriately, they may result in negative impacts. Another possible explanation is that it reflects port decision-makers' attitudes towards adaptation measures. Even with the availability of adaptation plans and programs, they prefer not to implement them, as they are too costly in terms of money, time, or human resources. Ports (e.g. the Port of San Diego) found it difficult to get close cooperation from other port stakeholders (e.g., business groups) that had their own concerns on the impacts of adaptation measures on, say, business interests and regional economy (cf. Messner et al., 2016). All these difficulties suggest the deficiency of the current planning paradigm in adaptation

- often initiated, and drafted, by the port authority based on experiences from climate change mitigation (especially the 'top-down' approach in controlling CO_2 emission/achieving CO_2 emission milestones). Also, it is interesting to note that, in many cases, ports' adaptation plan merges with mitigation measures, thus forming 'mitigation and adaptation plans' for the ports concerned (e.g., CMAP). Such a plan might raise port stakeholders' awareness on the necessity of ports' adaptation to climate change risk, but not enough to convince most (if not all) of them to actually transform constructive ideas into real, practical solutions. Understanding such, a paradigm shift from 'go it alone' (largely based on the port authority) to a more 'collaborative' approach is necessary. Adaptation to climate change is a complex and diverse issue and that, as pointed out by UNCTAD (2012), ports (and port authorities) should not expect the problem to be solved only through individual efforts. Other port stakeholders (e.g., terminal operating companies, shipping lines, real estate developers, yacht clubs, and all other parties using port lands) and external stakeholders (e.g., the local community, scholars, etc.) should work together in a collaborative way. With the rise of port-focal logistics (Ng and Liu, 2014) where ports have become more and more integrated with global supply chains, a paradigm shift in adaptation planning is urgently needed, in view of the growing importance of climate adaptation by (even more complex with more stakeholders and more diversified interests) supply chains.

CHAPTER 5: CASE STUDY

5.1 Physical setting

Port Metro Vancouver (PMV) is adjacent to 16 municipalities and crosses territories and treaty lands that belong to a couple of Coast Salish First Nations. The jurisdiction of the PMV's port authority encompasses more than 600 km of shorelines (InterVISTAS Consulting Inc., 2013), from Burrard Inlet down to the Fraser River and Roberts Bank. PMV administers water and land that are extremely critical to the municipal, provincial and national economy. Due to the nature of business, infrastructures and facilities of PMV are all positioned along sea shoreline and riverbank. Most of its marine cargo terminals are situated in the City of Vancouver and the City of North Vancouver, and there are also critical infrastructure and business activities (such as transition zones) along the Fraser River. In addition to 28 major deep-sea terminals, PMV is the home to three Class 1 railroads (PMV website).

5.2 Climate change

The risk management team at PMV has analyzed more than 100 types of risks. Due to the impacts on the environment and infrastructure, climate change is ranked among the 'list of top-12 major risk' that PMV is facing[8]. Interviewees agreed that the main impact posed by climate change risks at PMV is flooding from both the ocean and river sides.

5.2.1 Sea level rise

In a coastal line mapping by the Natural Resources Canada, the province of British Columbia (BC) is expected to have low sensitivity to SLR, thanks to its mountainous and high-relief landscape. However, still, it is projected to witness the impacts of SLR in the next century,

[8] Interviewee 6, January 29, 2016

and given the high intensity of infrastructure and business of billions of dollars positioned in this area, potential losses associated with these impacts can be enormous. Predominant components driving the rising water level can be changes from various geographical regions, such as 'changes in global ocean volume due to melting of ice caps, continental ice sheets and mountain glaciers', 'global and regional changes in ocean volume due to thermal expansion and salinity effects on water density' and 'regional volume changes due to dynamic atmospheric and ocean processes' (Province of British Columbia, 2008, p. 3). The province adopted a SLR curve by Ausenco Sandwell (2011) for planning and related policy-making and the projected base sea level will rise by 1 and 2 meter(s) by 2100 and 2200, respectively. The stated forecast is widely accepted and applied to scenario studies of shoreline and riverbank (BC Ministry of Forests, Lands and Natural Resource Operations, 2014a; Northwest Hydraulic Consultants Ltd., 2014). BC studied the impacts posed by SLR from multi-angles and identified primary influences as more flooding, coastal erosion, risks to infrastructure, and threats to ecology (Fraser Basin Council website, BC RAC: Coastal Flood Management). King tides and storm surges threat the daily operation of PMV. In particular, two king tides[9] in the December of 2012 and 2014 flooded low areas and put infrastructure at risk (e.g. temporary abandon of a parking lot and potential electrical components failure). Another key element that should be considered is waves effect. Wind develops high water levels, which are determined by wind strength, time of blowing and the open area that wind can travel. Coastal flooding is a synthetic consequence of SLR, storm surge and waves, and the floodplain is expected to expand over years (PMV, 2015).

5.2.2 Fraser River flooding

[9] Tidal impact magnifies in December due to the closest distance from the Earth to the sun.

The Fraser River originates from Mt. Robson (that forms part of the Canadian Rocky Mountains) and flows towards the western coastline of BC, draining around a quarter of the province (BC Ministry of Forests, Lands and Natural Resource Operations, 2014b). Unsurprisingly, it has a long history of flooding and at least has witnessed two great ones on record. In 1894, the largest event in the 167-year period through 2015 hit massive lands, exercising influences on half of the province. The floodplain was undeveloped at that time. Therefore, fairly tolerable damage was caused. However, when the second largest flooding took place in 1948, several dikes failed and the associated losses were valued as nearly $210 million (in 2010 dollars) (BC Ministry of Forests, Lands and Natural Resource Operations website, Dike management and safety). Several studies reveal that if floods of the similar magnitude as 1894 reoccur, the City of Chilliwack will suffer from economic damages of almost $1 billion, and even more for the City of Richmond (Fraser Basin Council website, Flood and the Fraser). Although no assessment studies have anticipated the potential damages to the entire Fraser Valley communities, taking the densely populated region and highly developed economy into consideration, the BC provincial government suggests that the overall value could be in tens of billions of dollars (BC Ministry of Forests, Lands and Natural Resource Operations website, Dike management and safety).

Fraser Basin Council, a non-profit organization dedicated to collaborate and coordinate issues on the Fraser River to advance sustainable development, introduces primary causes of river flooding, which covers 'heavy rainfall, spring freshets, ice jams, log jams, debris flows, sediment deposition, tsunamis and tidal cycles' (Fraser Basin Council, 2010, p.3). Spring freshets are a result of 'large spring snowpack with an extended period of hot weather' and 'large spring snowpack with wide-spread heavy rainfall' (BC Ministry of Forests, Lands and Natural Resource

Operations, 2014a, p.12). Freshets generated by snow-melting predominantly determine the hydrologic condition of the river. Global warming brings hot weather and speeds up snow melting in the rocky area where the Fraser River starts. On the other hand, the rising ocean water (a combined result of SLR, storm surge and wave effects) can lead to rivers and streams to back up (Fraser Basin Council, 2010). A joint study (BC Ministry of Forests, Lands and Natural Resource Operations, 2014a) argues that a 0.2 to 0.4m increase in flood level could occur as a result of the provincially recommended guideline of 1m SLR by the year 2100. Such water level rise may be especially challenging for communities located in the middle and lower valley. A flood of the similar magnitude to 1894 and 1948 flooding has a typical return period of 500 and 200 years. But with climate change impacts (a moderate scenario for the 1948 flood and an intense scenario for the 1894 flood), the return period is estimated to drop to 50 years. The possibility of a similar flood reoccurrence is anticipated to be one-in-three (Fraser Basin Council website, Flood and the Fraser).

5.3 Port actions

PMV is experienced and successful with gas emission measures (i.e. shore power projects and cargo-handling fee) and the mitigation approach is well developed, from the phase of planning to implementation. On the other hand, the adaptation part has been overlooked. Not until the past 2 or 3 years did the port start to give sufficient consideration to climate change impacts and combine such impacts with the increasing risk of flooding[10]. Peak flows at Hope (the very upstream part) are usually utilized to indicate the water level of the Fraser River and to develop flooding scenarios. In 2012, the annual maximum daily flows for Fraser River at Hope reached a hazardous level of 11,700 m^3/s, highest in the recent years (BC Ministry of Forests,

[10] Interviewees 1,2,3, January 7, 2016.

Lands and Natural Resource Operations, 2014a). This amount is larger than that of 2007 (10,800 m^3/s), when the provincial government funded $33 million to dike authorities for dike upgrades and other urgent flood mitigation projects to protect the floodplain from the significant flood threat (BC Ministry of Forests, Lands and Natural Resource Operations, 2014a; Fraser Basin Council website, Flood Projects). At that time, the port recognized the crucial impacts of climate change on the increasing flows and began to undertake adaptation actions more systematically. However, as adaptation to climate change is a new start, unsurprisingly, similar to other major ports around the world, the port is still trying to feel its way around. The engineering and maintenance team is assigned to take responsibility for adaptation work. Up to now, the port has not developed an adaptation plan to tackle adaptation issues, for it has not been able to define or establish an appropriate approach[11], and a large proportion of its work is collaborative regional efforts.

It is inevitable for PMV to focus on regional adaptation work rather than its individual efforts. On one hand, the port set about adaptation work within three years; therefore, it is very challenging for the port to have already become proficient in this domain by now. They lack relevant experience or appropriate method to undertake such work. On the other hand, climate change is a highly complicated problem, and the typical or accepted way to address it is a full set of actions, from problem identification, scenarios setting and potential loss estimation to option suggestion and fund raising, along with implementation and evaluation. Hence, the port has limited resources to engage on the whole adaptation chain. These evidences verify that it is reasonable and appropriate to study regional adaptation efforts. With recognition of flooding hazards posed by climate change risks, the port has been actively involving in two projects

[11] Interviewee 1, January 7, 2016.

during the past few years, one concentrating on coastal flood and the other dedicated to lower mainland flooding along the Fraser River.

5.3.1 Coastal flood risk assessment

The City of Vancouver (hereafter called the 'City'), located along the Pacific coastline, initiated and adopted Climate Change Adaptation Strategy in 2012 as a guideline to build a more sustainable and resilient city and to tackle the rising climate change issue. The City is the first Canadian municipality in doing so. A coastal flood risk assessment is proposed as the best practice and primary action in Phase 1 to feed into the option exploration and discussion in phase 2, and to facilitate actions in adaptation planning. The king tide in December 2012 also prompted the flood risk assessment project. Given interests of critical infrastructure and operations in the City, PMV joined the project as a funding partner.

In December 2014, the City made a public announcement on the risk assessment report prepared by the Northwest Hydraulic Consultants (2014). The study developed five scenarios for the risk modelling and accepted the third scenario as a base for vulnerability assessment and 'hot spot' mapping. The third scenario constitutes elements of year 2100, 1.0 m of SLR, 1:500 years as the return period and a joint probability method ('probability that any of high tide/Fraser flooding, storm surge and wave effect could take place at the same time, instead of a simple sum of these numbers', PMV, 2015, p. 35). In an example of flood risk mapping for Burrard Inlet, most of the port lands are expected to experience a flood depth (freeboard not included) of 0-50 cm, some with 50-100 cm and even 100-200 cm. When the flood depth reaches a level of 100-200 cm, the ground floor will be flooded and residents must be evacuated. Based on the flooding risk simulation, the City further drew a hot spot map to demonstrate the estimated vulnerability. The map presents that port business is located in a most flood-vulnerable area. Landing on the south shore of Burrard Inlet, two cruise ship terminals, two container terminals and five bulk terminals of the port will probably experience operational disruption. To monetize the consequences of flooding, the report adopted a model called Hazus, which is developed by the US Federal Emergency Management Agency in 1992. This methodology is a standard tool to estimate damages from natural hazards and this report firstly applied the Canadian version to a major flood study. The total financial loss was calculated to be approximately $660 million (believed to be underestimated, see PMV, 2015). The Hazus modeling only estimated direct tangible and some indirect tangible losses, with a particular focus on damages to buildings. It is believed that more inventories and indirect economic losses should be estimated in further studies. Although the calculated result is considered unreliable, the Hazus modeling still provides insights and a large-scale indicator of the potential losses caused by flooding.

5.3.2 Lower Mainland Flood Management Strategy

The Lower Mainland Flood Management Strategy (hereinafter called the 'Strategy') is launched in July 2014 and the study boundary starts from Hope to Richmond and from Squamish to White Rock (Fraser Basin Council website, Flood Management). The Strategy constitutes two phases. Phase 1 (2014-15) comprises evaluations of flood scenarios through hydraulic modelling and simulation, vulnerability, consequences and costs assessment and a review of the existing policies, practices and other relevant works, in an attempt to gain a better understanding of the current situation as well as potential risks in the future. The findings and insights from Phase 1 are expected to feed into Phase 2 (2016 ongoing), where strategies and options are developed, along with a focus on a sustained funding model and implementation.

Coordinated and facilitated by the Fraser Basin Council, the Strategy is an inter-jurisdictional effort that brings more than 40 partners together and works collaboratively towards the regional resilience to flooding along the Fraser Basin. Stakeholders are the Government of Canada, provincial ministries, 26 municipalities and other agencies (including PMV) that share common interests. They have completed Phase 1 and until late January 2016, report of Project 1, Lower Mainland Flood Management Strategy- Analysis of Flood Scenarios, has been published (Fraser Basin Council website, Flood Management). The report analyzed two coastal and two Fraser River flood scenarios using the joint probability approach and primarily delivered a map illustrating water levels at specific sites (Kerr Wood Leidal, 2015). The report also illustrated the difference in water levels between the 1894 flood without consideration of SLR and a 1 in 500-year AEP[12] flood combined with 1m SLR. However, a vast majority of the current protective works were built through the Fraser River Flood Control Program during 1968 and 1995. These protection works mainly followed the minimum provincial dike design standard set by the provincial government in the early 1970s, based on the 1894 flood magnitude plus a freeboard of 0.6 m in allowance for wave effect and uncertainties. Although there are upgrades in 2007 and the following years, many dikes are still below the current standards and their capability to resist with a major flood is questionable (The Association of Professional Engineers and Geoscientists of British Columbia, 2012).

5.4 Discussion and recommendation

Although the two initiatives are led by different agencies in the case of PMV, they were found to be quite similar, no matter from the adopted methodology to the components of project deliverables. From a holistic view, the two projects both try to investigate the current situation and explore future scenarios, for the sake of further adaptation planning. Interestingly, even with

[12] Annual Exceedance Probabilities (AEP) is the chance of a flooding event occurring annually. For example, if a flood has an AEP of 2%, then a flood of this magnitude is expected to take place once in 50 years (in other words, it has a return period of 50 years).

a better understanding of adaptation conditions, the adaptation process stagnates at the stage of knowledge sharing and exploration. It has to be admitted that the port did not undertake adaptation work until few years ago and it is possible that stakeholders just need more time to act. But more importantly, the interviewees on the whole demonstrated that these stakeholders find it difficult to proceed to the next stage of planning, funding and implementation.

The available adaptation options at PMV and its surrounding region were at first examined for an in-depth observation. Structural and non-structural actions are the two main categories for flood management options and the actions are classified by a study (Ausenco Sandwell, 2011) into four types. One is to protect (to build protective works and barriers) as a structural option, including dikes, floodwalls and foreshores. The remaining three are all non-structural options, namely, to accommodate (to accept occasional events and protect at the same time), to retreat (to move back) and to avoid (to limit development). In a project to estimate costs of adaptation to flooding (BC Ministry of Forests, Lands and Natural Resource Operations, 2012), the BC government held two option selection workshops, with attendees from the project team and municipal and provincial governments. Dike was chosen as the best option for 30 out of the 36 studied reaches (83%). Actually, dike is the most common solution to flooding in the province. It is possible that dike is the most cost-effective approach to protect the floodplain, but this phenomenon can also be explained as a reflection of the conventional thinking. The stakeholders take the dike option as granted because this is what have been done over centuries and the alternatives become inconceivable. Actors may focus on options that they deem appropriate (logic of appropriateness) (Pierson, 2000) and those under their control (Moser and Ekstrom, 2010), as argued as a cognitive constraint in the preconscious institutionalism (Roberts and Greenwood, 1997).

Current dikes are mainly constructed by the Fraser River Flood Control Program. During that period, the federal and provincial government both undertook half of investment in capital works, while rights-of-way and responsibilities of operation and maintenance fell into the local governments. In 2007, the BC government launched $100M over a decade for local governments to construct works in flood management. However, besides from rights-of-way and operation and maintenance, this program required the municipal authority to share up to 33% of the cost in capital works, hence not all local governments participated in the program because of their limited resources (The Association of Professional Engineers and Geoscientists of British Columbia, 2012). The institutional arrangement in BC is that the federal government devolves responsibility to local authorities and only under the condition that the local government agrees to take responsibilities for ownership, operation and maintenance, construction of a new dike will be approved. However, there are nearly 105 local entities (including municipal governments, dike districts and so on) that govern public dikes in the province (BC Ministry of Forests, Lands and Natural Resource Operations website, Dike management and safety). Diversities in these parties make it hard to set a unified standard. It can be seen that the conventional way for adaptation follows a bottom-up design, the senior governments offering funds and the local authorities participating voluntarily. However, it is questionable in terms of ethics, as people with the lowest adaptive capacity may be the most vulnerable ones exposed to climate change impacts.

As most of dikes follows the guidelines of 1970s and are under the contemporary standards, upgrade is extremely important and urgent. The province has estimated cost of dike upgrade in these reaches, and approximately 10 billion is required to accommodate 1m in SLR by the year 2100. The question of who should be responsible for what is still under debate. On the regional side, no one stands out to take the initiative and propose an action plan (emerging as a leadership problem). If a commercial agency like PMV takes the lead, jurisdiction will place it in an awkward position. If the senior government becomes the leader, as evidence show, a joint funding standard may not be applied to all stakeholders. Nevertheless, even if the senior government is capable of defining different approaches for the various agencies, given that funding allocation is a sensitive issue, it is very likely to raise the question of fairness. That is why the progress is stalled. After public consultation, stakeholders still have little knowledge of the proceedings for further directions.

For landlord ports such as PMV, the terminals identify their own responsibilities and the port authority does not run operations. It is still under debate whether the port should be responsible for adaptation works or it should alternatively share the costs of investment with the private operators. On one hand, considering the uncertainties (one nature of climate change adaptation in Figure 2.2) of climatic events, port stakeholders are not capable to robustly determine the cost-effectiveness of investment in adaptation measures. Consequently, they find it very challenging to make rational decisions. Commercial agencies, such as port authorities (of the commercial ports) and terminal operators, are expected to maximize the net profits to fulfil the requirements of their shareholders. Uncertainties in the evaluation of climatic events, particularly the failure to provide a reliable assessment of consequences via the Hazus modeling, discourage the port decision-makers to fully engage in the adaptation work out of functionality. Further studies, especially cost and benefit analysis, are extremely necessary to demonstrate the effectiveness of adaptation works. There are a plenty of studies on cost-effectiveness of mitigation actions (e.g. shore power projects), because mitigation consequences are straightforward to quantify. However, immeasurable and indirect effects of adaptive responses further provoke the urgent issue in evaluation of adaptation measures. Even with advanced approaches to minimize uncertainties, the decision-makers at PMV would require a numeric result to support their investment plans in adaptation. How to improve methodologies to overcome difficulties in measurement still remains a tough question in the adaptation research and port community. On the other hand, given that the time period of concession agreements is usually 30-50 years[13], private operators lack incentives to involve in climate change adaptation and to invest in proactive works that may benefit the next tenants instead of themselves. Even under the circumstance that impacts posed by climate change are rather serious and threaten their smooth operations, they can relocate their business at another nearby port with a potential relative low cost (compared with the investment in proactive adaptation). Hence, the tenants prefer to wait, which in return will establish the institutional legacy that the port authority is excepted to act as the sole planner and operator in climate change adaptation. The huge time gap between political life of decision-makers and lifespan of adaptation actions (dikes in this case) also discourages actors to make aggressive adaptation actions and stimulates incremental progresses instead. For climate change adaptation, future means decades or even centuries later, but in the eyes of politicians and private sectors, future means the following five years or even tomorrow.

Path dependency also attempts to embed the new emerging issue of climate change adaptation into the existing institutions. At PMV, the engineering team takes charge of adaptation efforts, mainly because one of their duties is to protect and maintain infrastructure. However, engineers have insufficient knowledge or expertise on port planning. It is the institution that mainstreams climate change adaptation into the present business. In the regional adaptation

[13] Interviewee 2, January 7, 2016.

projects, one critical problem is the lack of appropriate staffs[14]. On the stage of knowledge sharing, agencies send staffs that they deem the most appropriate or relevant, and after workshops or webinars, these attendees return to their daily work. When the organizers/ coordinators (the Fraser Basin Council in this case) make further movements, they find it very difficult to get access to the 'right' person. From the view of the attendees, climate change adaptation is only a new component in their responsibility, and considering its nature of uncertainty and long planning horizons, it is very likely that the attendees place adaptation at the bottom of their to-do list and focus on other prioritized work. In addition, observations of the two adaptation efforts at PMV reveal that the bottom-up approach is still adopted in the regional adaptation planning. The stakeholders participate in the programs voluntarily, without any significant change in the current stakeholder network. The running mechanism of these collaborative adaptation efforts is following the path created by previous regional programs.

Hence, although such council/ collaborative network (i.e. Fraser Basin Council) exists so as to advance the adaptation process, its effectiveness in stakeholder engagement is questionable. Climate change is a typical market failure issue. Its externality determines the vague responsibility allocation. Such institution fails to define and allocate adaptation responsibility (the 'clearly defined boundaries' principle in institutional design proposed by Huntjens et al., 2012), while the concept of 'act out of duty' in the institutional theory hinders actors to do more beyond their responsibilities. The incomplete and vague responsibility allocation gives excuses to stakeholders to involve in the adaptation efforts at a publically acceptable level (especially for private agencies in consideration of corporate social responsibilities). The institution also fails to provide a conflict solution and approaches to achieve collective choice (the 'conflict prevention

[14] Interviewee 5, January 21, 2016.

and resolution mechanisms' and 'collective choice arrangements' principles by Huntjens et al., 2012). Based on the observations on the Fraser Basin Council, the established network is rather fragmented from the angle of interests. Objectives and visions of different stakeholders are not synthesized, and actors interpret climate change adaptation into their business under various political, institutional and cultural circumstances. This network-based voluntary approach fails to provide a solution to the problem of uncertainty. Without hierarchic structure and governance interventions, actors participate in adaptation activities so as to achieve their anticipated maximized economic or social profits. Given such rationality in institutionalism, uncertainty discourages stakeholders to commit to sufficient adaptation involvements.

No matter in the regional projects or within the port, a funding problem originates from the undefined and vague allocation of responsibilities. Arguments of 'clearly defined boundaries' and 'equal and fair distribution of risks, benefits and costs' proposed by Huntjens et al., (2012) in the research field of climate change adaptation can be applied to the investment responsibility issue. A potential allocation method of usage basis reveals the above principles and may be implemented at port and on a regional level. Port authority and the tenants both benefit from economic activities in a disaster prone area. The port users will suffer from an expected cost resulting from a hazard event on a unit basis. A unit basis indicates that the more a user operates (and then generates revenue), the more cost caused by climate change impacts it faces. If the port authority makes an adaptation investment, at a certain chance (which needs to be further determined), this unit cost will be reduced. In other words, investment responsibility can be allocated based on benefit of each stakeholder gains from port-related activities. This is an idea inspired by the 'property right' in transaction cost economics (Brunner and Enting, 2014) and the 'Polluter Pays Principle' in mitigation strategy (Khan and Roberts, 2013) to motivate actors and mobilize resources. Of course, more elements should be considered to make this method feasible, which include and not limited to how to identify the scope of stakeholders, how to evaluate different effects of an adaptation investment on unit costs of various stakeholders, how to implement this method in real business (e.g. port authority and port users share costs of capital works or the port authority acts as the sole decision-maker of adaptation investments and develops a price mechanism based on the usage unit), and how this method will influence port competitiveness and users' choice.

Another recommendation is to establish a neutral agency which is capable of making decisions and taking responsive actions, as demonstrated in Figure 2.4. In the Lower Mainland Flood Management Strategy, working as the project manager and facilitator of communication, the Fraser Basin Council is a non-profit organization and has no power on any of the stakeholders to promote the progress. In most adaptation cases, the status quo is that interested parties get together, share knowledge and go back to continue their own business. Hence, a more suitably empowered agency is proposed, which can be formed as a committee, consisting of representatives/ decision-makers from all agencies that have interest in the regional adaptation. The committee may be composed of scientists, engineers, senior port managers, economists, community leaders and members of environmental groups. In addition, this recommendation is believed to address another proposition by Huntjens et al. (2012), namely the 'nested enterprises/polycentric governance'. Instead of identifying and relying on one single center of power, or the so-called leader in this thesis, the committee is a product of multiple authorities and collective organizations with power. Through this agency, representatives coordinate, discuss conflicts of interests, mobilize resources and work towards a mutually acceptable decision to make 'real' progress.

From the lesson learned from PMV, a promising avenue is proposed for ports to adapt to climate change impacts: a flexible combination of engagement in collaborative work and individual efforts. Given the fact that study of climate change adaptation is a new topic, the whole research community is still attempting to find appropriate methods to address it. Under the present circumstance, the port authority, especially for the one as a profit maximizer, should mainly focus on collaborative projects to gain more experience so as to define an appropriate framework for its adaptation work. This recommendation is not intended to discourage ports from individual adaptation work. Instead, it provides a strategic path for ports to make the best use of their limited resources (particularly funding) and avoid blind and futile attempts. With the development in adaptation work, ports should gradually shift its work focus from the collaborative projects to its own adaptation efforts.

CHAPTER 6: CONCLUSION

6.1 Summary

Climate change adaptation is a relatively new and emerging topic at ports, their surrounding regions, and the supply chains. Due to their proximity to the sea, ports are exposed to a variety of climate change risks. To mitigate the potential negative impacts posed by climate change, ports and port stakeholders have engaged in various adaptation efforts. However, most ports and the stakeholders are still working to enhance their understanding and knowledge of climate change and finding it a challenge to proceed to the next stage of adaptation planning and action implementation. The present study is designed to tackle this problem by investigating why stakeholders are not aware of or comfortable with proceeding with planning and implementation.

Recognizing the importance of institutional barriers that hinder climate change adaptation, the thesis critically reviews the impacts of institutions on the process of climate adaptation planning. How and why institutions can act as impediments is analyzed and explained by comparing key features of climate change adaptation and institutions. These two fields act contrary to one another. In particular, the concept of thick institutionalization is adopted to examine institutional deficiencies in the current setting. Understanding that the existing stakeholder network fails to solve the issues of responsibility allocation and diversified informal institutions, a constructive suggestion is proposed on how the institutional structure of planning should change so as to achieve a breakthrough.

Secondly, given that the literature review emphasizes the role of informal institutions (e.g. values and perceptions), the thesis explores port decision-makers' knowledge and perception about adaptation measures by studying two typical climate change risks (SLR and high winds and storms). Deposition and sedimentation are the most important impacts caused by SLR on ports, while the most significant impact caused by higher winds and storms is downtime. No matter in frequency or severity of consequences, port decision-makers have a far better knowledge of impacts caused by high winds and/or storms than those by SLR. Moreover, their perceptions about frequency are clearer than those about consequences. Also, the results indicate that port decision-makers anticipate both SLR and storms & high winds will give rise to more serious even disastrous impacts in the next decade. However, they hold serious doubts about the effectiveness of various adaptation measures. Port adaptation plans and implementations are unsystematic, and the adaptation work is still at the embryonic stage. On the other hand, the 'regional diversification' of climate change impacts is examined as a critical element in port adaptation planning. It is consequently pivotal to tailor-make adaptation methods in accordance with a specific climate change risk. On account of the complexity of climate change problems, a paradigm shift in adaptation planning approach is imperative and collaborative work with all of the stakeholders involved is required, especially in view of the rise port-focal logistics and the growing importance of climate adaptation by global supply chains.

Additionally, with acknowledgement of the regional nature of climate change problem, the thesis examines the adaptation work through a case study of PMV and focuses on its regional engagement. The aim is to further explain the findings in the survey through empirical evidence and to examine the constructive suggestion proposed at the end of the literature review. The primary impact of climate change on the port has been identified as increase in frequency and intensity in coastal and river flooding. As the largest Canadian port, PMV pioneers in GHG emission control (i.e., mitigation), but did not recognize the significance of adaptation measures until recent years and has not yet developed an adaptation plan. Inexperienced in adaptation work, the port currently centers around regional efforts. The case of PMV shares considerable commonalities with many other ports that have undergone climate adaptation planning. Although with a better understanding of adaptation conditions, the stakeholders still find it difficult to proceed to the 'next level' of planning, funding, and implementation. Through archival analysis and interviews, funding is identified as the biggest obstacle that has made the adaptation path rather rocky. The question of who is responsible for what is still under debate. To address this issue, the author trace back to the undefined and vague allocation of responsibilities, and further, recommend a potential allocation method based on the usage unit. Establishment of a neutral empowered agency (like a collaborative network) is proposed to address the leadership problem, promote the adaptation process and make further progress. A flexible combination of engagement in collaborative projects and individual efforts is also recommended to ports for their adaptation work.

6.2 General discussion

Adaptation is an inherently complex approach to tackle the problem of climate change, thanks to its three characteristics- uncertainty, immeasurable and indirect effects, and long time horizon. This thesis is expected to investigate the contemporary issue in climate change adaptation in port areas and provide strategic suggestions through theoretical analysis, a global survey and a case study.

One significant finding in the survey is that climate change impacts were forecasted to be more serious by the port decision-makers. It suggests these stakeholders are aware that adaptation actions must be undertaken to build and enhance the adaptive capacity to respond to climate change risks. Indeed, stakeholders at Port Metro Vancouver have recognized such necessity and urgency and have embarked adaptation efforts through regional adaptation projects in the recent years. In addition, the Fraser Basin Council takes the initiative to organize workshops and webinars for stakeholders to share knowledge and experience regarding climate change adaptation. The finding is in accord with the recent studies indicating that adapting ports to impacts caused by climate change is of significant importance (Becker et al., 2013). Hence, it could conceivably be suggested that the anticipated crucial impacts posed by climate change have raised the port stakeholders' awareness of responding to these effects.

Another interesting finding of the regional diversification regarding the effectiveness of adaptation measures may be explained by the different institutional settings at ports in Asia and North America. Despite of the privatization reforms, the Asian ports are still retaining or influenced by the centrally planned institutional system (Tongzon et al., 2015). Ports from North America, however, are exercising more decentralized power in a relatively autonomous environment. Asian ports operate in a more hierarchical governance system and at the same time are expecting to receive more funds from the central government. With a higher percentage of investment from the different levels of governments, Asian ports may be more financially insensitive to adaptation measures, thus tending to hold a more positive attitude towards the effectiveness of adaptation efforts.

In contrast to the recognition of more serious impacts in the future, surprisingly, the results of the survey demonstrate that port decision-makers are on the whole indifferent with the effectiveness of adaptation measures. Previous studies have emphasized the importance of barriers in the process of adaptation so as to explain the neutral attitudes of the stakeholders. The results of the case study support the idea of technological barriers and institutional barriers. First, consequences of impacts cannot be adequately assessed due to a lack of an appropriate and robust methodology. This argument is supported by the finding that the respondents of the survey have a better understanding of frequency than severity of consequence. Indeed, despite the fact that the Hazus modeling is regarded as the most advanced tool to estimate climate change impacts, it still failed to provide a robust and reliable assessment in one of the PMV's regional adaptation efforts. Consequently, stakeholders find it very difficult to undertake 'real' adaptation actions without sufficient knowledge or concrete ideas on the potential effects of adaptation efforts.

Turning now to the institutional barriers, two different institutional theories (rational choice institutionalism and path dependency) could be employed to explain the adaptation problem in regional efforts at PMV and its surroundings. First, assuming the stakeholders are rationalists, uncertain return is insufficient to motivate them to invest in adaptation projects to build resilience. Hence, it is urgent to develop and improve the methods of impact assessment so as to further reinforce stakeholders' knowledge on adaptation. Second, port stakeholders mainstream climate change adaptation into their current business due to path dependency. The new business (climate change adaptation) is assigned to the existing departments and inevitably, follows the conventional ways to address climate-related issues. The institutional legacies have additionally determined the current 'go it alone' strategy in adaptation planning (Ng et al., 2016a). An adaptation plan is mainly written by one agency rather than through a collaborative process. The aforementioned CMAP at Port of San Diego was suspended due to its incomplete concern of interests of different stakeholders. The award-winning adaptation plans in Marin County in California, USA have also not been implemented because (at least partly) it followed the current planning strategy and failed to encourage stakeholders to actively engage in the process of adaptation planning (Ekstrom and Moser, 2013).

Researchers have emphasized the role of informal institutions (e.g. values, attitudes, and beliefs) in the decision-making process as well as the generation of an aggressive amendment rather than an incremental modification. The finding of indifferent and even negative attitudes towards the effectiveness of adaptation measures is likely to discourage stakeholders to engage in adaptation efforts. It is pivotal to shift perceptions of the stakeholders to facilitate the process of adaptation. Here is noted that without collaboration with other stakeholders, change in the attitude of one single stakeholder may not significantly influence the process of a regional adaptation project. The interest of each stakeholder needs to be concerned to facilitate the collaborative work. These findings raise the intriguing questions regarding the transformation of the current stakeholder network. Based on sociological institutionalism, the proposed network on how the institutional structure of planning (see Figure 2.4) should change can serve as a potential solution to resolve the conflicts of interests among stakeholders. Future studies on this topic are therefore recommended.

6.3 Contribution, limitation and implementation

The study highlights the crucial role of institutions play in climate change adaptation and identifies gaps in the existing literature. The discussion of contrary natures between climate change adaptation and institutions, as well as institutional deficiencies of the current stakeholder network, have significant implications for understanding how and why institutions hinder the process of climate change adaptation. The analysis of the relationship between climate change adaptation and institutions has extended the knowledge of institutional barriers. A constructive suggestion is proposed for future academic study and planning efforts in practice. The present study also takes the initiative to investigate the perceptions and knowledge of port decision-makers have about climate change adaptation by a statistical approach, rather than a qualitative analysis of arguments. Additionally, it says ‘no’ to conventional thoughts that as long as we invest in adaptation measures, they will take effect. One the other hand, it is consistent with the existing literature about the complexity of adaptation planning to climate change as well as port managers’ doubts in adaptation. While this study fails to confirm the correlation between climate change knowledge and concrete ideas of adaptation measures, it partially substantiates that more climatic knowledge can contribute to more concrete ideas on climate change adaptation. To author’s best knowledge, this is the first study reporting regional diversification in climate change adaptation through quantitative analysis. The regional diversification therefore assists in our understanding of the significant role of tailor-made adaptation methods. Finally, it enhances the knowledge of the current situation at ports. Through a case study of Port Metro Vancouver, the study offers evidence to the contemporary dilemma in port’s adaptation to climate change and takes the initiative to call attention to its regional efforts. Instead of simply emphasizing the importance and urgency of adaptation planning, innovative propositions (mainly based on institutional theory) are put forward to facilitate adaptation process and in addition, suggest a strategic avenue for ports to make the best use of their limited resources.

Admittedly, the theoretical proposition is a preliminary idea that needs to be further developed and verified. Also, a broader spectrum of relevant literature in a greater volume should be included to support a more comprehensive review. Field practices being applied to verify the theoretical proposition are largely from the seaport sector, thereby there is a need to examine the findings and suggestions with examples from other sectors. There are also several limitations in the survey. One source of weakness in this study is the scaling of each element. They are scaled into interval numbers, ranging from 1 to 5. A further test is required to clarify whether it is an appropriate way. Moreover, it is necessary to develop a scaling method for ordinal data in similar studies. Another limitation is the geographical distribution of the samples. Since about half of the respondents are from Asia and the other 20% from North America, it is not easy to generalize a precise picture of adaptation planning in ports all around the world. More samples from different regions, in particular, from Australia, Europe, South America and Africa, should be involved in further research. Besides, given the fact that 10% of the participants are from developing countries, by this means, the outcomes of this survey mainly explicate the present situations in ports from developed countries. Meanwhile, the sample size of developing countries is not big enough to support statistical significance, hence in further studies, more data from developing countries can be collected and analyzed to investigate if there is a gap between ports from the North and the South in climate change adaptation. The small sample size of respondents from North America does not allow a highly robust result for regional analysis. Further work needs to be done to establish the regional diversification in climate change adaption. Here is also noted that given the survey explores perceptions of decision-makers, potential bias caused by the different roles of respondents (as an individual or a professional) should be removed. Future trials should assess this difference from the perspective of social psychology. Besides, it is unfortunate that recommendations in the case study are preliminary ideas that need to be further developed and verified. Given that these propositions are based on analysis of the Vancouver case, the applicability to other ports needs to be further examined.

But having said so, the study is a pioneer study in addressing an important issue that urgently requires more research. It identifies a gap in institutional barriers in climate change adaptation and strives to fill this gap by bridging literature from climate change and institutional theories. The results of the survey do not only illustrate the indifferent, and sometimes resentful, attitudes of ports to develop adaptation measures, but also highlight the necessity of a paradigm shift in the adaptation planning approach. The thesis also highlights the importance of not just raising awareness of climate change adaptation but also exploring appropriate and effective methods through the paradigm shift. This study can act as a solid platform for further research, and helps decision-makers to develop effective adaptation solutions and guidelines so as to ensure that ports, their surrounding regions and the global supply chains will be more resilient to the impacts posed by climate change.

REFERENCES

Amundsen, H., Berglund, F., & Westskog, H. (2010). Overcoming barriers to climate change adaptation—a question of multilevel governance? *Environment and Planning C: Government and Policy, 28*(2), 276-289.

Araral, E. (2013). A transaction cost approach to climate adaptation: insights from Coase, Ostrom and Williamson and evidence from the 400-year old zangjeras. *Environmental Science & Policy, 25*, 147-156.

Ausenco Sandwell. (2011). *Climate change adaptation guidelines for sea dikes and coastal flood hazard land use: Guidelines for management of coastal flood hazard land use.* Vancouver, Canada: Ausenco Sandwell.

Badie, B., Berg-Schlosser, D., & Morlino, L. (2011). Comparative politics. In *International encyclopedia of political science.* (Vol. 2, pp. 342-349). Thousand Oaks: SAGE Publications.

Barnett, J., Evans, L., Gross, C., Kiem, A. S., Kingsford, R. T., Palutikof, J. P., . . . Smithers, S. G. (2015). From barriers to limits to climate change adaptation: path dependency and the speed of change. *Ecology and Society, 20*(3), 5-15.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: study design and implementation for novice researchers. *The qualitative report, 13*(4), 544-559.

BC Ministry of Forests, Lands and Natural Resource Operations. (2012). *Cost of Adaptation - Sea Dikes & Alternative Strategies Final Report*. Vancouver, Canada: BC Ministry of Forests, Lands and Natural Resource Operations.

BC Ministry of Forests, Lands and Natural Resource Operations. (2014a). *Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios*. Vancouver, Canada: BC Ministry of Forests, Lands and Natural Resource Operations.

BC Ministry of Forests, Lands and Natural Resource Operations. (2014b). *Fraser River Design Flood Level Update - Hope to Mission Final Report.* Vancouver, Canada: BC Ministry of Forests, Lands and Natural Resource Operations.

BC Ministry of Forests, Lands and Natural Resource Operations Website, Dike management and safety. Date of access: 18/01/2016. Retrieved from http://www.env.gov.bc.ca/wsd/public_safety/flood/fhm-2012/safety_index.html.

Becker, A., Inoue, S., Fischer, M., & Schwegler, B. (2012). Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. *Climatic change, 110*(1-2), 5-29.

Becker, A., Acciaro, M., Asariotis, R., Cabrera, E., Cretegny, L., Crist, P., . . . Naruse, S. (2013). A note on climate change adaptation for seaports: a challenge for global ports, a challenge for global society. *Climatic change, 120*(4), 683-695.

Becker, A., Matson, P., Fischer, M., & Mastrandrea, M. D. (2015). Towards seaport resilience for climate change adaptation: Stakeholder perceptions of hurricane impacts in Gulfport (MS) and Providence (RI). *Progress in Planning, 99*, 1-49.

Becker, A. (2016). The state of climate adaptation for ports and the way forward. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 265-274). Abingdon: Routledge.

Birkman, J., Garschagen, M., Kraas, F., & Quang, N. (2010). Adaptative Urban Governance: New Challenges for the Second Generation of Urban Adaptation Strategies to Climate Change. *Sustainability Science, 5*(2), 185–206.

Bouriaud, L., Marzano, M., Lexer, M., Nichiforel, L., Reyer, C., Temperli, C., . . . Taylor, P. (2015). Institutional factors and opportunities for adapting European forest management to climate change. *Regional Environmental Change, 15*(8), 1595-1609.

Broom, L., & Selznick, P. (1955). *Sociology: A Text with Adapted Readings*. New York: Row, Peterson.

Brown, S., Nicholls, R. J., Hanson, S., Brundrit, G., Dearing, J. A., Dickson, M. E., . . . Hinkel, J. (2014). Shifting perspectives on coastal impacts and adaptation. *Nature Climate Change, 4*(9), 752-755.

Brunner, S., & Enting, K. (2014). Climate finance: A transaction cost perspective on the structure of state-to-state transfers. *Global Environmental Change, 27*, 138-143.

Burch, S. (2010). Transforming barriers into enablers of action on climate change: insights from three municipal case studies in British Columbia, Canada. *Global Environmental Change, 20*(2), 287-297.

Central Intelligence Agency Website. Date of access: 20/10/2014. Retrieved from https://www.cia.gov/library/publications/resources/the-world-factbook/.

Chhetri, N. B., Easterling, W. E., Terando, A., & Mearns, L. (2010). Modeling path dependence in agricultural adaptation to climate variability and change. *Annals of the Association of American Geographers, 100*(4), 894-907.

City of Vancouver. (2012). *Climate Change Adaptation Strategy.* Vancouver, Canada: City of Vancouver.

Cullinane, K., & Song, D.-W. (2002). Port privatization policy and practice. *Transport Reviews, 22*(1), 55-75.

Denzau, A. T., & North, D. C. (1994). Shared mental models: ideologies and institutions. *Kyklos, 47*(1), 3-31.

Dietz, T., Ostrom, E., & Stern, P. C. (2003). The struggle to govern the commons. *Science, 302*(5652), 1907-1912.

Dixon, W. J., & Mood, A. M. (1946). The statistical sign test. *Journal of the American Statistical Association*, 41(236), 557-566.

Eisenack, K., Moser, S. C., Hoffmann, E., Klein, R. J., Oberlack, C., Pechan, A., . . . Termeer, C. J. (2014). Explaining and overcoming barriers to climate change adaptation. *Nature Climate Change, 4*(10), 867-872.

Ekstrom, J. A., & Moser, S. C. (2013). Institutions as key element to successful climate adaptation processes: results from the San Francisco Bay Area. In Moser, S.C., & Boykoff, M.T. (Eds.), *Successful Adaptation to Climate Change - Linking Science and Policy in a rapidly changing World* (pp. 97–113). Abingdon: Routledge.

Ekstrom, J. A., & Moser, S. C. (2014). Identifying and overcoming barriers in urban climate adaptation: case study findings from the San Francisco Bay Area, California, USA. *Urban Climate, 9*, 54-74.

Esteban, M., Takagi, H., & Shibayama, T. (2016). Adaptation to an increase in typhoon intensity and sea level rise by Japanese ports. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 117-132). Abingdon: Routledge.

Fraser Basin Council. (2010). *Environmental Protection in Flood Hazard Management: A Guideline for Practitioners*. Vancouver, Canada: Fraser Basin Council.

Fraser Basin Council Website, BC RAC: Coastal Flood Management. Date of access: 18/01/2016. Retrieved from http://www.fraserbasin.bc.ca/ccaq_bcrac_flood.html.

Fraser Basin Council Website, Flood and the Fraser. Date of access: 19/01/2016. Retrieved from http://www.fraserbasin.bc.ca/water_flood_fraser.html.

Fraser Basin Council Website, Flood Management. Date of access: 19/01/2016. Retrieved from http://www.fraserbasin.bc.ca/water_flood.html.

Fraser Basin Council Website, Flood Projects. Date of access: 19/01/2016. Retrieved from http://www.fraserbasin.bc.ca/water_flood_projects.html.

Fünfgeld, H., & McEvoy, D. (2011). *Framing climate change adaptation in policy and practice*. Working paper, Victorian Centre for Climate Change Adaptation Research, Melbourne.

Füssel, H.-M., & Klein, R. J. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic change, 75*(3), 301-329.

Garrelts, H., & Lange, H. (2011). Path dependencies and path change in complex fields of action: climate adaptation policies in Germany in the realm of flood risk management. *Ambio, 40*(2), 200-209.

Hall, P. A., & Taylor, R. C. (1996). Political science and the three new institutionalisms. *Political studies, 44*(5), 936-957.

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change, 19*(2), 240-247.

Heir, T., & Weisæth, L. (2006). Back to where it happened: Self-reported symptom improvement of tsunami survivors who returned to the disaster area. *Prehospital and disaster medicine, 21*(2), 59-63.

Hoddinott, S. N., & Bass, M. J. (1986). The dillman total design survey method. *Canadian family physician, 32*, 2366-2368.

Huntjens, P., Lebel, L., Pahl-Wostl, C., Camkin, J., Schulze, R., & Kranz, N. (2012). Institutional design propositions for the governance of adaptation to climate change in the water sector. *Global Environmental Change, 22*(1), 67-81.

ICLEI Canada and FCM. (2008). *Partners for climate protection: five-milestone framework for reducing greenhouse gas emissions*. Ontario, Canada: ICLEI Canada and FCM.

Intergovernmental Panel on Climate Change (IPCC). (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the Intergovernmental Panel on Climate Change*. In: SREX, eds. Field, C. B. et al. Cambridge, UK, and New York, NY, USA.

InterVISTAS Consulting Inc. (2013). *2012 Port Metro Vancouver economic impact study – final report*. Vancouver, Canada: InterVISTAS Consulting Inc.

Keohane, R. O., & Victor, D. G. (2011). The regime complex for climate change. *Perspectives on politics*, *9*(01), 7-23.

Kerr Wood Leidal. (2015). *Lower mainland flood management strategy - analysis of flood scenarios*. Vancouver, Canada: Kerr Wood Leidal.

Khan, M. R. & Roberts, J. T. (2013). Towards a binding adaptation regime: three levers and two instruments. In Moser, S. C., & Boykoff, M. T. (Eds.), *Successful Adaptation to Climate*

Change - Linking Science and Policy in a rapidly changing World (pp. 132-148). Abingdon: Routledge.

Kingston, C., & Caballero, G. (2009). Comparing theories of institutional change. *Journal of Institutional Economics, 5*(02), 151-180.

Klein, J. (2016). Embeddedness of climate change adaptation: established procedures and contending discourses for flood protection in Espoo, Finland. *Local Environment*, *21*(2), 254-271.

Klein, R. J., Nicholls, R. J., Ragoonaden, S., Capobianco, M., Aston, J., & Buckley, E. N. (2001). Technological options for adaptation to climate change in coastal zones. *Journal of Coastal Research*, 531-543.

Knatz, G. (2016). Foreword. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. xxvii-xxviii). Abingdon: Routledge.

Lawrence, J., Sullivan, F., Lash, A., Ide, G., Cameron, C., & McGlinchey, L. (2015). Adapting to changing climate risk by local government in New Zealand: institutional practice barriers and enablers. *Local Environment, 20*(3), 298-320.

Lemieux, C. J., & Scott, D. J. (2011). Changing climate, challenging choices: identifying and evaluating climate change adaptation options for protected areas management in Ontario, Canada. *Environmental management, 48*(4), 675-690.

Marshall, G. R. (2013). Transaction costs, collective action and adaptation in managing complex social–ecological systems. *Ecological Economics, 88*, 185-194.

McCrum-Gardner, E. (2008). Which is the correct statistical test to use? *British Journal of Oral and Maxillofacial Surgery, 46*(1), 38-41.

Messner, S., Becker, A., & Ng, A. K. Y. (2016). Port adaptation for climate change: The role of stakeholders and the planning process. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 9-23). Abingdon: Routledge.

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences, 107*(51), 22026-22031.

Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., Van Vuuren, D. P., . . . Meehl, G. A. (2010). The next generation of scenarios for climate change research and assessment. *Nature, 463*(7282), 747-756.

Ng, A. K. Y., & Pallis, A. A. (2010). Port governance reforms in diversified institutional frameworks: generic solutions, implementation asymmetries. *Environment and Planning A, 42*(9), 2147-2167.

Ng, A. K. Y., Becker, A., & Fischer, M. (2013a). A theoretical discussion on climate change, port adaptation strategies and institutions. Proceedings of the Canadian Transportation Research Forum (CTRF), Halifax, NS, Canada, 10-11 June.

Ng, A. K. Y., Chen, S.-L., Cahoon, S., Brooks, B., & Yang, Z. (2013b). Climate change and the adaptation strategies of ports: The Australian experiences. *Research in Transportation Business & Management, 8*, 186-194.

Ng, A. K. Y., & Liu, J. (2014). *Port-focal logistics and global supply chains*. Basingstoke: Palgrave Macmillan.

Ng, A. K. Y., Wang, T., Yang, Z., Li, K. X., & Jiang, C. (2016a). How is Business Adapting to Climate Change Impacts Appropriately? Insight from the Commercial Port Sector. *Journal of Business Ethics*, 1-19.

Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P, & Yang, Z. (2016b). Time to act: the criticality of ports in adapting to the impacts posed by climate change. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 1-8). Abingdon: Routledge.

Nicholls, R. J., Hallegatte, S., Corfee-Morlot, J., Chateau, J., Muir-Wood, R., Hanson, S., . . . Patmore, N. (2008). *Ranking port cities with high exposure and vulnerability to climate extremes*. OECD Environment Working Paper No. 1. Organisation for Economic Co-operation and Development, Paris.

Northwest Hydraulic Consultants Ltd. (2014). *City of Vancouver coastal flood risk assessment final report.* Vancouver, Canada: Northwest Hydraulic Consultants Ltd.

Notteboom, T., De Langen, P., & Jacobs, W. (2013). Institutional plasticity and path dependence in seaports: interactions between institutions, port governance reforms and port authority routines. *Journal of Transport Geography, 27*, 26-35.

Nursey-Bray, M., Blackwell, B., Brooks, B., Campbell, M. L., Goldsworthy, L., Pateman, H., . . . Francis, J. (2013). Vulnerabilities and adaptation of ports to climate change. *Journal of Environmental Planning and Management, 56*(7), 1021-1045.

Osthorst, W., & Mänz, C. (2012). Types of cluster adaptation to climate change. Lessons from the port and logistics sector of Northwest Germany. *Maritime Policy & Management, 39*(2), 227-248.

Peñalba, L. M., Elazegui, D. D., Pulhin, J. M., & Victor O. Cruz, R. (2012). Social and institutional dimensions of climate change adaptation. *International Journal of Climate Change Strategies and Management, 4*(3), 308-322.

Pierson, P. (2000). The limits of design: explaining institutional origins and change. *Governance, 13*(4), 475-499.

Port Metro Vancouver (PMV). (2015). Flood risk analysis at Port Metro Vancouver (PMV). Date of access: 12/01/2016. Retrieved from http://www.fraserbasin.bc.ca/_Library/CCAQ_BCRAC/ccaq_rising_oceans-smith.pdf.

Port Metro Vancouver (PMV) Website. Date of access: 29/01/2016. Retrieved from https://www.portmetrovancouver.com.

Province of British Columbia (BC). (2008). *Projected sea level changes for British Columbia in the 21st Century*. Vancouver, Canada: Province of British Columbia.

Ritchie, A., De, J., Hugi, C., & Copper, D. (2005). *Service Contract on Ship Emissions: Assignment, Abatement and Market-Based Instruments*. Task 2c-SO2 Abatement, Final Report for European Commission Directorate General Environment.

Roberts, P. W., & Greenwood, R. (1997). Integrating transaction cost and institutional theories: Toward a constrained-efficiency framework for understanding organizational design adoption. *Academy of Management Review, 22*(2), 346-373.

Roland, G. (2004). Understanding institutional change: fast-moving and slow-moving institutions. *Studies in Comparative International Development, 38*(4), 109-131.

Root, L., van der Krabben, E., & Spit, T. (2015). Bridging the financial gap in climate adaptation: Dutch planning and land development through a new institutional lens. *Journal of Environmental Planning and Management, 58*(4), 701-718.

Scholz, R. W., Blumer, Y. B., & Brand, F. S. (2012). Risk, vulnerability, robustness, and resilience from a decision-theoretic perspective. *Journal of Risk Research, 15*(3), 313-330.

Scott, W. R. (2014). *Institutions and organizations: Ideas, interests, and identities*. Thousand Oaks: SAGE Publications.

Selznick P. (1994). *The Moral Commonwealth: Social Theory and the Promise of Community*. Berkeley: University of California Press.

Sheldon, M. R., Fillyaw, M. J., & Thompson, W. D. (1996). The use and interpretation of the Friedman test in the analysis of ordinal-scale data in repeated measures designs. *Physiotherapy Research International*, 1(4), 221-228.

Slack, B., & Comtois, C. (2016). Climate change and adaptation strategies of Canadian ports and shipping: The case of the St. Lawrence-Great Lakes system. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 45-58). Abingdon: Routledge.

Tellis, W. M. (1997). Application of a case study methodology. *The qualitative report, 3*(3), 1-19.

The Association of Professional Engineers and Geoscientists of British Columbia. (2012). *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC*. Vancouver, Canada: The Association of Professional Engineers and Geoscientists of British Columbia.

Tongzon, J. L., Ng, A. K. Y., & Shou, E. C. (2015). Institutions, transport infrastructure governance, and planning: lessons from the corporatization of port authorities in East Asia. *Environment and Planning C: Government and Policy, 33*(6), 1467-1483.

UNCTAD. (2012). *Ad Hoc Expert Meeting on Climate Change Impacts and Adaptation: A Challenge for Global Ports: Geneva, Palais des Nations, 29-30 September 2011: Main Outcomes and Summary of Discussions*. Geneva, Switzerland: UNCTAD.

Verny, J. (2016). Arctic transportation and new global supply chain organizations: The Northern Sea Route in international economic geography. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 246-264). Abingdon: Routledge.

Walker, B. J., Adger, W. N., & Russel, D. (2015). Institutional barriers to climate change adaptation in decentralised governance structures: Transport planning in England. *Urban Studies*, *52*(12), 2250-2266.

Walker, W. D., Liebl, D. S., Gilbert, L. E., LaGro, J., Nowak, P., & Sullivan, J. (2010). *Adapting to climate change: Why adaptation policy is more difficult than we think (and what to do about it)*. Wisconsin Initiative on Climate Change Impacts.

Waters, E., Barnett, J., & Puleston, A. (2014). Contrasting perspectives on barriers to adaptation in Australian climate change policy. *Climatic change, 124*(4), 691-702.

Xiao, Y.-b., Fu, X., Ng, A. K. Y., & Zhang, A. (2015). Port investments on coastal and marine disasters prevention: Economic modeling and implications. *Transportation Research Part B: Methodological, 78*, 202-221.

Yang, Z., Ng, A. K. Y., Lee, P. T. W., Wang, T., Rodrigues, V. S., Pettit, S. & Harris, I. (2015). Modelling risk based cost analysis of port adaptation measures to climate change. Proceedings of the International Conference of the Asian Logistics Round Table (ALRT), Taipei, Taiwan, 31 August - 1 September 2015.

Yuen, C. A., Zhang, A., & Cheung, W. (2012). Port competitiveness from the users' perspective: An analysis of major container ports in China and its neighbouring countries. *Research in Transportation Economics*, 35(1), 34-40.

Zhang, D., Wan, C., & Yang, Z. (2016). Modeling and evaluation of green port development: a case study on Tianjin port. In Ng, A. K. Y., Becker, A., Cahoon, S., Chen, S.-L., Earl, P., & Yang, Z (Eds.), *Climate Change and Adaptation Planning for Ports* (pp. 133-152). Abingdon: Routledge.

APPENDIX A- SURVEY

1. Participant’s agreement

□ I understand to my satisfaction the information regarding participation in the project and agree to participate in this survey.

2. Date

DD/MM/YYYY ______/_____/________

BACKGROUD INFORMATION

3. What’s the name of your port?

____

4. What is the name of your terminal (if applicable)?

____

5. Where is your port/terminal located (please be as specific as possible**)?**

____

6. Your name and title (optional)

____

7. Your current position in port/terminal

____

8. Your contact details (optional)

____

EXISTING RISKS AND IMPACTS DUE TO CLIMATE CHANGE

How, if at all, has climate change impacted your port/terminal in the past 5 years?

Description of Variables

Frequency:
Very frequent - Happened more than once per year

Frequent - Happened on average once per year
Sometimes - Happened more than once, but fewer than 10 times in the past decade

Seldom - Happened once in the past decade
Never - Did not happen in the past decade

Severity of consequences:
Catastrophic - Very severe economic loss and/or disruption to facilities/systems/services from which the port did not recover
Critical - Severe economic loss and/or disruption to facilities/systems/services requiring a long period and high cost of recovery for entire port
Major - Significant economic loss and/or disruption to facilities/systems/services requiring a long period of time and high cost of recovery for some aspects of port operations
Minor - Some economic loss and/or disruption of facilities/systems/services requiring some time and cost of recovery for all or part of the port
Negligible - A bit of disruption to the facilities/systems/services, and possibly with some economic loss, but with no real impacts on the continuance of services, nor significant time and cost of recovery

9. Sea level rise impacts in the past 5 years

	Frequency	Severity of consequences
(a) Sea level rise resulted in higher waves that damaged your port/terminal's facilities and/or ships berthed alongside		
(b) Transport infra- and superstructures (like cranes and warehouses) and utilities in your port/terminal were flooded or damaged because of sea level rise		
(c) Coastal erosion occurred at or adjacent to your port/terminal		
(d) Deposition and sedimentation occurred along your port/terminal's channels		
(e) Overland access (road, railway) to your port/terminal was limited due to more incidents of flooding		

10. Increased intensity and/or frequency of high winds and/or storms due to climate change in the past 5 years

	Frequency	Severity of consequences
(a) Waves due to stronger storms damaged port/terminal facilities and/or ships berthed alongside		
(b) Transport infra- and superstructures (e.g., cranes and warehouses) and/or utilities in the port/terminal were flooded or damaged due to higher winds and/or storms		
(c) Your port/terminal operation was shut down due to higher winds and/or storms		
(d) Overland access (road, railway) to your port/terminal was limited due to higher winds and/or storms		

RECENT IMPACTS AND ADAPTATION MEASURES TO CLIMATE CHANGE

RISKS

11. If your port/terminal has been impacted by climate change (e.g., sea level rise, increased intensity and/or frequency of high wind and/or storm events) in the last decade, please describe the event(s) here:

____

12. If you answered yes to Question 11, what were the approximate financial costs of damage (in US dollars)?

____

13. If you answered yes to Question 11, what were the other consequences of these events in the weeks, months, years following?

____

14. Do you address the risks posed by climate change on your port/terminal? (Please choose ALL items which CURRENTLY apply to your port/terminal)

□ Climate change written into strategic plan
□ Climate change addressed in specific climate change planning document
□ Climate change part of the design guidelines or standards
□ Climate change included and funded in your port/terminal's budget
□ Climate change specifically addressed in your port/terminal's insurance
□ Climate change not addressed at this moment

□ I do not know/I am not sure
□ Other (please specify) ________________________________

15. Please choose ALL of the following protective measure(s) that your port/terminal has CURRENTLY in place:

□ Flood insurance
□ Storm insurance
□ Storm barrier
□ Breakwater
□ Protective dike
□ Storm protections other than a dike or breakwater
□ Port lands elevated above historical height
□ Storm response plan
□ Drainage pumps
□ Seawall
□ Future plans to replace/upgrade existing structures
□ I do not know/I am not sure
□ Other (please specify) ________________________________

CLIMATE CHANGE RISKS IN THE FUTURE WITHOUT ADAPTATION MEASURES

Which climate change risks and impacts would you expect your port/terminal be exposed to in the FUTURE if your port/terminal does NOT undertake any adaptation measures?

Description of Variables

Timeframe for when you expect to first see this impact:
Very Long - More than 20 years
Long - Approximately 15 years
Medium - Approximately 10 years
Short - Approximately 5 years
Very short - Less than 1 year

Severity of consequences:
Catastrophic - Very severe economic loss and/or disruption on the facilities/systems/services requiring a very long period and very high cost of recovery
Critical - severe economic loss and/or disruption on the facilities/systems/services requiring a long period and high cost of recovery
Major - Significant economic loss and/or disruption on the facilities/systems/services requiring certain length of time and cost of recovery

Minor - Some economic loss and/or disruption on the facilities/systems/services requiring some time and cost of recovery
Negligible - A bit of disruption on the facilities/systems/services, and possibly with some economic loss, but with not real impacts on the continuance of services, nor does it requires significant time and cost of recovery

Likelihood that the event will occur:
Very High - It is very highly likely that the stated effect will occur, with a probability of around 90% of at least one such incident within the indicated timeframe
High - It is highly likely that the stated effect will occur, with a probability of around 70% of at least one such incident within the indicated timeframe
Average - It is likely that the stated effect will occur, with a probability of around 50% of at least one such incident within the indicated timeframe
Low - It is unlikely that the stated effect will occur, with a probability of around 30% of at least one such incident within the indicated timeframe
Very low - It is very unlikely that the stated effect will occur, with a probability of around 10% of at least one such incident within the indicated timeframe

16. Sea Level Rise

	Timeframe	Severity of consequences	Likelihood
(a) Higher waves which will damage port/terminal's facilities, and ships berthed alongside			
(b) Transport infra- and superstructures and utilities in the port/terminal will get flooded or damaged due to flooding			
(c) Coastal erosion will occur at or adjacent to port			
(d) Deposition and sedimentation will occur along port/terminal's channels			
(e) Overland access (road, railway) to port/terminal will be limited due to flooding			

17. Increased intensity and/or frequency of high wind and/or storms

	Timeframe	Severity of consequences	Likelihood
(a) Higher waves that will damage port/terminal's facilities, and ships berthed alongside			
(b) Transport infra- and superstructures and utilities in the port/terminal will get flooded or damaged in more intense or frequent storms			
(c) Downtime in port/terminal operation due to the increase of high winds and storms			
(d) Overland access (road, railway) to port/terminal will be limited due to more intense/frequent storms			

CLIMATE CHANGE RISKS IN THE FUTURE WITH ADAPTATION MEASURES

In your opinion, how would your level of climate change risks change if your port/terminal HAS IMPLEMENTED adaptation measures over the next decade?

Description of Variables

Financial cost of adaptation:
Very High - involves a very high financial cost so as to comprehensively address the stated potential effect
High - involves a high financial cost so as to comprehensively address the stated potential effect
Average - involves a significant financial cost so as to comprehensively address the stated potential effect
Low - involves a financial cost (though not that significant) so as to comprehensively address the stated potential effect
Very low - involves a minimal financial cost so as to comprehensively address the stated potential effect

Timeframe for when you expect to first see this impact:
Very Long - More than 20 years
Long - Approximately 15 years
Medium - Approximately 10 years
Short - Approximately 5 years

Very short - Less than 1 year

Severity of consequences:
Catastrophic - Very severe economic loss and/or disruption on the facilities/systems/services requiring a very long period and very high cost of recovery
Critical - severe economic loss and/or disruption on the facilities/systems/services requiring a long period and high cost of recovery
Major - Significant economic loss and/or disruption on the facilities/systems/services requiring certain length of time and cost of recovery
Minor - Some economic loss and/or disruption on the facilities/systems/services requiring some time and cost of recovery
Negligible - A bit of disruption on the facilities/systems/services, and possibly with some economic loss, but with not real impacts on the continuance of services, nor does it requires significant time and cost of recovery

Likelihood that the event will occur:
Very High - It is very highly likely that the stated effect will occur, with a probability of around 90% of at least one such incident within the indicated timeframe
High - It is highly likely that the stated effect will occur, with a probability of around 70% of at least one such incident within the indicated timeframe
Average - It is likely that the stated effect will occur, with a probability of around 50% of at least one such incident within the indicated timeframe
Low - It is unlikely that the stated effect will occur, with a probability of around 30% of at least one such incident within the indicated timeframe
Very low - It is very unlikely that the stated effect will occur, with a probability of around 10% of at least one such incident within the indicated timeframe

18. Sea Level Rise

	Financial cost of adaptation measure	Timeframe for when you expect this impact	Severity of consequences	Likelihood that the event will occur
(a) Higher waves will damage port/terminal's facilities, and ships berthed alongside (Adaptation Measure: build new breakwaters and/or increase their dimensions)				
(b) Transport infra- and superstructures and utilities in the port/terminal will get flooded or damaged due to flooding (Adaptation				

Measures: Improve transport infra- and superstructures resilience to flooding)

(c) Transport infra- and superstructures and utilities in the port/terminal will get flooded or damaged due to flooding (Adaptation Measures: Elevation of port land)

(d) Coastal erosion will occur at or adjacent to port (Adaptation Measure: Protect coastline and increase beach nourishment programs)

(e) Deposition and sedimentation will occur along port/terminal's channels (Adaptation Measure: Increase and/or expand dredging)

(f) Overland access (road, railway) to port/terminal will be limited due to flooding (Adaptation Measure: Improve quality of land connections to port/terminal)

(g) Overland access (road, railway) to port/terminal will be limited due to flooding (Adaptation Measure: Diversify land connections to port/terminal)

(h) All the risks and impacts above (Adaptation Measure: Move facilities away from existing locations which are vulnerable to climate change risks and impacts)

19. Increased intensity and/or frequency of high wind and/or storms

	Financial cost of adaptation measure	Timeframe for when you expect this impact	Severity of consequences	Likelihood that the event will occur
(a) Downtime in port/terminal operation due to the increase of high winds and storms (Adaptation Measure: Improve management to prevent effects)				

20. Increased intensity and/or frequency of high wind and/or storms

	Timeframe for when you expect this impact	Severity of consequences	Likelihood that the event will occur
(a) Higher waves that will damage port/terminal's facilities, and ships berthed alongside (Adaptation Measure: Build new breakwaters and/or increase their dimensions)			
(b) Transport infra- and superstructures and utilities in the port/terminal will get flooded or damaged in more intense or frequent storms (Adaptation Measure: Improve transport infra- and superstructures resilience to flooding)			

(c) Overland access (road, railway) to port/terminal will be limited due to more intense/frequent storms (Adaptation Measure: Improve quality of land connections to port/terminal)

(d) Overland access (road, railway) to port/terminal will be limited due to more intense/frequent storms (Adaptation Measure: Diversify land connections to port/terminal)

(e) All the risks and impacts above (Adaptation Measure: Move facilities away from existing locations which are vulnerable to climate change risks and impacts)

21. Additional comments: ______________________________

22. If you or other staff members of your port/terminal want to be considered for future dialogues on the risks and impacts posed by climate change on ports/terminals, please indicate your e-mail and those of interested staff members: ______________________________

THIS IS THE END OF THE SURVEY. THANK YOU VERY MUCH FOR YOUR TIME AND CONTRIBUTIONS!!

APPENDIX B- INTERVIEW QUESTIONS

Part A: Planning approach of climate change adaptation and other programs

A1. In the past 20 years, Port Metro Vancouver has designed and implemented a significant number of projects. What do you think is the typical planning approach? For instance, does it follows a top-down design or bottom-up approach? Do you think this (these) approach(s) work well? Why do you think so?

A2. Located at western coast of Canada, your port attempts to protect its assets against potential impacts of climate change, which is referred as adaptation efforts to climate change risks. In your opinion, does the planning approach of adaptation differ from others? Why do you think so? Do you believe the existing approach of adaptation planning work well? Can you explain why? If not, what method do you think should be adopted for the effectiveness of adaptation planning?

Part B: Identification of climate change risks to Port Metro Vancouver and studying of current conditions

B1. What do you think are the main (say, top 3) climate change risks faced by your port? What impacts (in terms of frequency, severity of consequences) have they brought to your port during the last decade? Is there any adaptation action to address the problem caused by climate change risks? If yes, what are they, which climate change risks have you addressed and how do they work?

B2. How do you identify these main climate change risks? For example, do you learn them from an existing document of your port (for instance, strategic planning document, a study conducted by port to study current conditions, or a dedicated study by an external party, e.g.

consulting firm, which is employed by the port), based on your experience and knowledge or from climate change works by external parties, e.g. academic researchers and government?

B3. As a port planner, do you find 'national' and 'international' research works about climate change and port adaptation valuable? When preparing adaptation planning of your port, do you actually refer to these works? From which aspects, do you think it is helpful with your port planning? On the contrary, in your opinion, what are the major shortcomings/weaknesses/problems of using these 'high level' studies into the planning of your port? Why do you think so?

B4. Following the above question, how do you fit their knowledge and findings into your local conditions? In other words, how do you bridge the 'high level information' or findings from a different background to situations of your own port? When taking advantage of these research works, have you come across any difficulties? How did you overcome these obstacles?

Part C: Analysis of climate change risks, action and timeframe design

C1. What principles do your port follow to prioritize identified climate change risks? In other words, how do your port determine the top issues (the most urgent and pressing risks that need immediate actions)? Why do you believe these principles help you to sort out priorities reasonably? In your opinion, is the ranking affected by amount of knowledge that the port has on a specific climate change risk? For example, if the port is struck by storms annually, thus knowledgeable with storm forecast and associated losses, while, it is not familiar with impacts of sea level rise, then it is more likely for the port to prioritize storms over sea level rise.

C2. When preparing adaptation planning, are actions ranked in accordance with the priority of its associated climate change risk? That is to say, if a climate change risk is ranked as the top one, actions to address this problem will be prioritized accordingly. If not, what are the determinants of action priority? In what way do these determinants work together to indicate ranking of various actions?

C3. What is the time horizon for the adaptation strategies (say, 10, 20, 50 years, or even more)? Are there any specific reasons or reference points that such strategies are developed with the indicated timeline (e.g., in coherent with the Port Master Plan, budgetary purpose, etc.)? Among the adaptation strategies, what are those that need to (and will) be done 'immediately' (or very short term), and what are those which can be done 'in the long term' (with no real urgency)?

Part D: Stakeholders, interest groups and external parties

D1. Who are the stakeholders (i.e. port tenants, environmental groups, federal/ provincial/ local government, and other land users) involved during the process of adaptation planning? What are their contributions to adaptation (planning, implementation, maintenance and evaluation), respectively? Who else do you think should be consulted? Why do you think so?

D2. From your view, who are the main 'victims' (the parties who have to live with losses brought by climate change risks) of climate change risks posed to your port? What have they done to adapt to these risks? What is the outcome of their efforts? Who do you think is not the main 'victims', but also should contribute to climate change adaptation?

D3. 'Port 2050' by Deloitte Inc. provides insights of sustainable development at your port. What do you think about the role played by external parities in adaptation planning and implementation? Do you think compared with stakeholders, external parties will provide a relatively neutral assessment and/or service? Do you think involvement of external parties should be encouraged or avoided? Why do you think so?

Part E: Investment, implementation and evaluation

E1. How is the investment responsibility of adaptation actions allocated? Is the allocation largely similar with other climate change actions, say, mitigation project shore power, or not? What do you think is the appropriate way to allocated investment responsibility, for example, by value of assets exposed to climate change risks?

E2. Is there any method to evaluate the effectiveness of adaptation efforts? If yes, how do they work? Who is responsible to monitor implementation of the adaptation actions and who is responsible for the project evaluation in real business? Do you think it is the right party to undertake these responsibilities? Why do you think so? If no, which party do you think should be involved?

E3. Do you think time horizon influences effectiveness evaluation of adaptation efforts? In other words, what do you think should be the suitable timeframe to assess adaptation efforts?

Part F: Overall view of port adaptation to climate change

F1. Do you think your port's adaptation plan is an 'action plan', which involves assessment of the current situation, identification of climate change risks, prioritization of these issues, design and implementation of adaptation plans and evaluation of adaptation actions? That is to say, it is not a study paper of current conditions, but a plan with 'real actions'?

F2. Overall, from design to implementation and evaluation, in your opinion, on which stage have you meet the most difficulties? Or put in another way, on which stage do you find it is the most hard to process further? Why do you think so? What have you done to deal with the problems? In addition, what do you think should be done to solve the problem?

Part G: Forecast of climate change risks in the next decade

G1. In your opinion, will the identified top climate change risks change over the next decade? If yes, how will these main climate change risks change? Why do you think so? What should port do with the changing environment accordingly? Have any of these changes recorded in port planning documents, say, strategic planning and sustainability report?

G2. Do you think impacts posed by the main climate change risks will become more serious? Why do you think so? What adaptation plan has been designed or been designing to tackle this problem? If none, what do you believe are the main reasons?