Adapting to the Risks and Uncertainties Posed by Climate Change on Ports

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Abstract

Climate change has become a critical issue in port supply chains in recent decades, involving a variety of disciplines and posing substantial challenges to ports due to their high vulnerability. To date, there is insufficient research on how to minimize these uncertainties in terms of decision-making and port planning. Also, even for port operators who have taken countermeasures to minimize the impacts of climate change on their ports, some strategic and planning problems still remain. Based on the above issues, this thesis proposes that it is pivotal to enhance the awareness of the community's consideration of the risks and uncertainties of climate change impacts on ports, and calls for adaptation strategies to cope with climate change impacts from the perspective of port supply chains. Through an extensive literature review, and a nation-wide survey, as well as in-depth interviews in case studies focused on a seaport, an inland port and railway (Port of Montreal, CentrePort Canada and Hudson Railway respectively), this thesis provides and overview of the risks and uncertainties posed by climate change to Canadian ports. Through both quantitative (SPSS in survey) and qualitative analyses (interviews in the case study), it is expected to fill the gaps of regional studies focused on Canada and the under-researched areas including dry ports, port supply chains and adaptation port planning by considering the risks and uncertainties posed by climate change.

Keywords: climate change, risk, uncertainty, adaptation, planning

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Chapter One: Introduction

1.1 Introduction

Ports play a significant role in human civilization and commerce by serving as catalysts for economic growth and development of trade (World Bank, 2010). Ports act as gateways to trade and provide access to global markets for both coastal and landlocked countries. As Canada has the world's longest coastline, around 23% of Canadians live in coastal communities, and the oceans sector generated approximately USD20.0 billion of Canada's gross domestic product (GDP) in 1996 (DFO, 2008), the ports of Canada have been playing an indispensable role in the environment, economy and social development.

Climate change has become a critical issue in recent decades, involving a variety of disciplines and posing substantial challenges to ports, the economy and the whole of society due to the high vulnerability of ports to the effect of climate change. The total economic loss due to service disruptions alone can reach the billions of euros/dollars (e.g., Haveman and Shatz, 2006). The potential risks on ports posed by climate change are also by the fact that sea level could be as much as 80 cm higher than they currently are by 2100 (Schaeffer et al., 2012). Due to the frequently climate-related incidences, including temporary and permanent flooding arising from sea-level rise, high winds and storm surges (Hanson and Nicholls, 2012; Asariotis and Benamara, 2012) and a series of second-order consequences, climate change jeopardizes not only the efficiency and profitability of ports and the benefits to publics that depend on the functions of ports, but also the operation of global supply-chains and human welfare (e.g., Becker et al., 2013). In particular, ports have evolved from a simple node to occupying a role as a strategic component of the supply chain (Song and Panayides, 2008; Ng and Liu, 2014), which magnifies the impacts of climate change on ports, related stakeholders and industries including tourism, fisheries, manufactories, etc.

These impacts of climate change on ports can be divided into two categories: those on seaports and those on dry ports. Seaports, which connect to transportation routes followed by most world commodities, play a dominant role in national economies and regional development. Given that fact that seaports are often located in the most vulnerable areas, which are susceptible to the climate-associated impacts including sea-level rise (SLR) and increased storm intensity or at the mouths of rivers which are susceptible to flooding, current research mainly focuses on the impacts on seaports. The impact on seaports can be summarized into sea-level rise (SLR), high winds, storm surges (Hanson and Nicholls, 2012; Asariotis and Benamara, 2012), and muskeg and permafrost in Arctic areas (e.g., Churchill, Canada). For instance, from 1960 to 2010, at least one tropical storm passed within 50 km of 32% of the world's seaports (Becker et al., 2013). In the Alaskan Arctic, thawing permafrost could softens tundra to limit exploration during warm months, which hinders shipment of goods and requires more investments in infrastructure, and which in turn incurs additional labor costs (Conley et al., 2013). Likewise, in the Arctic and Northern Hemisphere, the ice sheets in Greenland and Antarctic have shrunk substantially in the past decade, as have glaciers, sea ice and spring snow cover, all of which have required port authorities to adapt shipping plans from a global perspective (Qin et al., 2013). Given the high frequency and severity of the impacts of climate change on seaports, some port authorities have recognized this problem and taken effective countermeasures to cope with them (e.g., Vancouver, Canada; San Diego, USA)(Becker, et al., 2013; Port of San Diego 2013; Messner et al., 2013).

Admittedly, there is no clear consensus in the definition of dry ports, a term that could be synonymous with inland terminals (UNCTAD, 1982). Nevertheless, dry ports can be regarded as distribution centers where freight (de-) consolidation takes place, performing similar functions to seaports, include cargo handling, providing intermodal transport connections, information exchange and other value-added services such as custom clearance, inspections, storage, maintenance and repair of empty containers, and tax payments (Bresford and Dubey, 1990; United Nations Economic Commission For Europe (UNECE), 2001). The development of a dry port can be beneficial to increase coastal port capacity and productivity, while reducing transport costs, traffic congestion, air pollution, and accidents (Rahimi et al., 2008; Roso, 2007; Roso, 2008; Wang and Wei 2008). In particular, a dry port is able to decrease carbon dioxide emission by 25%, which is attributed to the fact that road transportation is substituted with rail transport which has a smaller relative carbon footprint size (Bresford and Dubey, 1990; Roso, 2009a; Roso, 2009b). Therefore, the development of dry ports contributes to an environment-friendly society while enjoying more natural advantages over seaports since they are far away from storm-impacts geographically. Nevertheless, since most of the focus of the risks of climate change is on seaports, rather than on dry ports (e.g., CentrePort Canada) until now, there has been very limited research figuring out the potential risks or uncertainties of climate change on dry ports. Planners typically consider the short-term returns, but some potential catastrophes, such as flooding and other extreme events could result in uncertainties in the use of inland navigation, disrupting entire transportation systems and jeopardizing the operation and competitiveness of ports (USCCSP, 2008; Koetse and Rietveld., 2009). Understanding such, this thesis initially classifies the impacts on dry ports into extreme weather, flooding, precipitation change and landslide, which will be explained further.

Because of the diversity among different regions (e.g., in developing countries and developed countries), severity of catastrophes (e.g., in hurricane belts and inland areas), and other variable factors, the impacts of climate change on ports are also diverse (i.e., Becker et al., 2013). As the United States Environmental Protection Agency (USEPA) reported, "most ports do not appear to be thinking about, let alone actively preparing to address, the effects of climate change" (USEPA, 2008, pp.1), and so some underlying uncertainties are easily ignored, especially by dry ports planners.

Based on the concepts from IPCC (2012), "risk" in this thesis can be understood 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"(IPCC, 2012, pp.32). Meanwhile, "uncertainty" is "the propensity or predisposition to be adversely affected, including the characteristic of a person or group that influences their capacity to anticipate, cope with, resist, and recover from the adverse effects of physical events" (IPCC, 2012, pp. 32, as cited by Becker, forthcoming, pp.267). Both risk and uncertainties can produce negative and positive impacts on objectives (e.g., ISO 31000(2009), n.d. as cited by Purdy (2010)).

In addition, given the differences of interpretation among port planners and stakeholders about the risk and potential uncertainties, patterns in port planning by considering climate change impacts are case-by-case (Ng et al., 2013a). Up to now, there has been insufficient research on minimizing these uncertainties in decision-making and port planning (NRC, 2010). The results from a global survey about knowledge, perceptions, and planning effects among port administrators (Becker et al., 2012) showed that although world port community has concerned with impacts of climate change, it is highly urgent to acquire more specific information from the scientific community to make good decisions.

Also, even for port operators who have taken countermeasures to minimize the impacts of climate change on their ports, some strategic and planning problems still remain. One of the main issues is of climate change strategies. It is worth mentioning that the strategies in tackling climate change can generally divided into adaptation and mitigation strategies. According to the definition from United Nations Framework Convention on Climate Change (UNFCCC), adaptation to climate change is “the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”, while mitigation is “a human intervention to reduce the sources or enhance the sinks of greenhouse gases” (GHG)(UNFCCC, n.d.). There is abundant research focused on measuring, controlling and reducing CO_2 and greenhouse gas (GHG) emissions (e.g., Patterson et al., 2008), as well as the de-carbonization of transportation (Geels, 2012; Schwanen et al., 2012; Watson, 2012). These research initiatives are not confined to the academics in green shipping in attempt to minimize the GHG emissions by modeling and other improving approaches (e.g., Berechman and Tseng, 2012; Corbett et al., 2009), but also in green policies on ports to improve their operation and maximize efficiency (e.g., Chang and Wang, 2012; Chin and Low, 2010). It is obvious that current research tends to focus on mitigating climate change issues on transport infrastructure and ports operation rather than take adaptation measures (Ng et al., 2013a). This bias arises partially because proactive adaptation to minimize vulnerabilities is more cost-effective than mitigation or reactive strategies (Pielke, 2007; Stern and Britain, 2006) and because there are more anticipated regulations or global attention to CO_2 issues (Becker et al., 2012). Whereas mitigation strategies failed to address all the deleterious risks, adaptation strategies are needed to develop in more detail. What is more, as Becker et al (2013) suggested, further study of adaptation measures requires focused research by considering the feasibility and prioritization of adaptation measures for specific ports and regions. This thesis highlights the impacts of climate change and the corresponding adaptation strategies under the background of Canada to fill the current gap in this field.

Another issue is that current port planning may not address the climate change impacts adequately. The first problem is that a relatively short planning cycle (typically 5-10 years) does not correspond to infrastructure lifespan (typically more than 50 years), which leads to the complexity in planning (ICFI, 2008; Kintisch, 2008; Ng, 2012). Meanwhile, scientific information inadequately matches shorter-range planning horizons in port community (Becker et al, 2012), which prevents the judgment of port planners from the level of impacts. Furthermore, the lack of engineering and design standards to guide decision-making is another barrier for port planners. Accordingly, there is an urgent need to establish broader collaboration between ports and the scientific community to provide precise data for strategic port planning and shift their attention from physical and technical issues of engineering projects alone to more holistic planning, investment and operation (Becker et al, 2013).

The above stories reveal an unclear picture that the existing port planning for climate change is in line with a conventional way because of multiple uncertain factors. This thesis is also complementary to the book titled *"Climate Change and Adaptation Planning for Ports"* (e.g., Ng et al., forthcoming). It is important for senior policymakers, industrial practitioners and researchers to understand the dynamics between climate change, adaptation planning of ports and transportation infrastructures and to improve current adaptation planning with comprehensive guidance, innovative assessment approaches and global experiences.

1.2 Primary Research Questions and Objectives

Based on the above questions in current research, the author proposes two primary research questions in this thesis:

1) What are the main impacts of climate change on Canadian ports?

2) What are the major challenges in adapting to climate change for Canadian ports?

Starting with the overview of the above research questions, this thesis has the following four objectives:

(1) To emphasize the significance of uncertainties that climate change poses to port planning and to call for more attention by port planners and stakeholders to these risks and uncertainties.

(2) To investigate the general situation of climate change and adaptation planning at Canadian ports.

(3) To lay a foundation of theory on initiating and improving adaptation planning of port and supply chains by integrating consideration of climate change risks and uncertainties into ports planning.

(4) To provide workable suggestions for global ports planning by drawing from the experiences of Canadian ports.

This thesis argues that it is very important to enhance the awareness of the community's consideration of the uncertainties of climate change and its effects on ports, and will suggest adaptation strategies to cope with climate change risks from the perspective of port supply chains. By extensive literature review, survey and case study focused on two Canadian ports (Port of Montreal and CentrePort Canada) and a railway (Hudson Bay Railway), it aims to illustrate a general situation of the uncertainties posed by climate change among Canadian ports, analyze the current measures and problems in handling with the issues of climate change and put forward adaptation strategies and relevant advices to port planners and stakeholders. It is expected that this thesis will fill the gaps among regional studies focused on Canada and the under-researched areas including dry ports, supply chains and strategic port planning by considering the uncertainties of climate change.

1.3 Rationale/ Concerned Engagement

Three theories, including the theory of path dependence, stakeholder management and supply chain risk management, are investigated to address the primary research questions and to achieve the objectives in this thesis.

Path dependence theory has been applied to the studies of long-term strategic port planning (Dooms et al, 2013). Pearson (2000) and Kay (2005) suggested that the concept of path dependence is related to analysis of 'temporary dynamics', which emphasizes that significant changes in investment strategy and governance are often attributed to the shift of exogenous events (such as climate change impacts) and role of stakeholders. Long-term, strategic planning based on real stakeholder inclusion could play an important role in governance change and development (Dooms et al, 2013). In this regard, to establish a resilient framework for a port's adaptation planning to minimize climate change risks and impacts, port authorities should take into account uncertainties of climate change and its impacts on the port's stakeholders.

Stakeholder theory originated from the field of strategy, and the stakeholder is defined as "any group or individual who can affect or is affected by the achievement of the organization's objective" (Freemen, 1984, pp.53). 'The stakeholder theory is "managerial" and recommends the attitudes, structures, and practices that, taken together constitute a stakeholder management philosophy' (Donaldson and Preston, 1995, pp.67). Supply Chain Management with respect to ports means that the port, as its core enterprise, effectively combines and coordinates its service providers (i.e., transportation, handling, inventory) with customers (i.e., shippers, shipping companies) into a system and distributes the correct number of goods at the right time to the right place in order to maximize the efficiency and profits of entire supply chain (Cheng and Zhu, 2011). This requires a comprehensive stakeholder management process where port planners emphasize the role, responsibility and relevance of stakeholders, and consider both internal and external uncertainties in port supply chains. As Dooms et al. (2013) pointed out that there are divergent preferences for different stakeholders for further port development, and accordingly how to balance the multiple benefits of port stakeholders in port supply chain is another question. Therefore, long-term, strategic port planning based on stakeholder management would contribute to change in the broader port region and port supply chains.

Although there is widespread recognition that a port is a key node in a supply chain, and supply chain management should be applied to the port sector, port risk management has not been given sufficient attention. Current research in port supply chain risk management tends to focus on identification of disruptions and mitigation countermeasure for catastrophic events (i.e., Guerrero et al., 2008). Meanwhile, most researchers tend to be concerned with risk factors in the change in demand and the market in supply chains (e.g., Das, 2011). However, given the fragility and complexity of port supply chains, adaptation planning by considering uncertainties in climate change should be applied in port supply chain risk management.

On the basis of the theory of path dependence theory, stakeholder management, and supply chains risk management, this thesis aims to provide an innovative framework of a strategic port planning by considering uncertainties of climate change. Based on an extensive literature review and theoretical foundations, a theoretical framework is constructed and three hypotheses and propositions are put forward in chapter 2. Afterwards, in chapter 3, the methodologies, including a nation-wide survey and two in-depth case studies (a port supply chain of CentrePort Canada and Hudson Bay Railway, as well as Port of Montreal), are elaborated respectively. In chapter 4, through conducting a domestic survey among 21 Canadian ports (both seaports and dry ports), it is expected to illustrate an overall perspective of climate change impacts on ports in Canada: accessing the perceptions of port planners and other stakeholders on climate change risks and uncertainties, as well as relevant port planning and adaptation measures to cope with climate change impacts. Subsequently, two case studies (CentrePort and Hudson Bay Railway in Manitoba, and Port of Montreal) are conducted based on a few semi-structured interviews in chapters 5 and 6, respectively. Finally, this thesis concludes with a general discussion and implications for further study in chapter 7.

Chapter Two: Literature Review & Theoretical Framework

2.1 Literature Review

2.1.1 Climate change impacts on ports

In 2009, Becker et al (2012) conducted a global survey about knowledge, perceptions, and planning effects among port administrators The survey demonstrated that nearly half of the respondents believed climate change would impose negative impacts on their operations in the coming decade; 86% of respondents agreed that the perceived issues should be tackled by the international port community; 66% of them felt they were not well informed about the direct impacts of climate change. This perception might be attributed to the uncertainties in scientific models of climate change (Becker et al., 2012). Also, this survey revealed that port authorities tend to underestimate the risks of climate change. There was no standard policy to deal with this issue, and only 44% of respondents had specific measures to cope with the impacts of climate change. When it comes to the most concerning issues, 38% and 15% expected SLR would rise 0.5-1 meters and more than 1 meter respectively, but 64% of them though it is unnecessary to add more measures to cope with the rise. Another survey conducted in 2005 and 2006 by a research group from Texas A&M University also supported these results: few respondents have adequate measures in place, or even have taken initial steps on plans (Bierling and Lorented, 2008). Similarly, in California, one of the most progressive state of the US, the expected risks of climate change and SLR on maritime facilities were generally ignored, while the SLR was anticipated to reach 1.4 meters by 2100 (California State Lands Commission, 2009). One reason stems from the diversification in different regions, severity of catastrophes, institutional capacities of ports (Becker et al., 2012) and other variable factors. In addition, given the differences of interpretation in the risk or potential uncertainties among port planners and stakeholders, there were no standard patterns in port planning by considering climate change impacts (Ng et al., 2013a)

However, the risks and potential uncertainties of climate change on the economy and environment of ports are numerous and the effects would persist for months or years. For example, for seaports, the fierce storm “Sandy” swept through the New York City and surrounding region. Since a proactive plan for infrastructure and operation was lacking, the storm led to a weeklong shutdown of one of the largest container ports in America and economic damages reached USD50 billion (EQECAT Inc., 2012). For dry ports, planners typically consider the short-term returns, but some potential catastrophes, such as flooding and other extreme events, could result in higher uncertainties in the use of inland navigation, disrupting entire transportation systems and the operation and competitiveness of ports. (USCCSP, 2008; Koetse and Rietveld, 2009).

2.1.2 Climate change strategies

Even for port operators who have taken countermeasures to minimize the impacts of climate change on their ports, some problems still remain. One of the main issues is climate change strategy. It is worth mentioning that the strategies for tackling with climate change can generally divided into adaptation and mitigation strategies. According to the definition from United Nations Framework Convention on Climate Change (UNFCCC), adaptation to climate change is “the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”, while mitigation is “a human intervention to reduce the sources or enhance the sinks of greenhouse gases” (GHG)(UNFCCC, n.d.).

Ports tend to place more importance on mitigation strategies than adaptation strategies. There is abundant research focusing on measuring, controlling and reducing CO_2 and Greenhouse Gas (GHG) emissions (e.g., Patterson, Ewing and Haider, 2008), as well as the de-carbonization of transportation (Geels, 2012; Schwanen et al., 2012; Watson, 2012). These studies are not limited to academic research in green shipping so as to minimize GHG emissions by modeling and other improved approaches (e.g., Berechman and Tseng, 2012; Corbett, Wang and Winebrake, 2009), but also in green policies on ports to improve their operation and maximize efficiency (e.g., Chang and Wang, 2012; Chin and Low, 2010). It is obvious that current research tends to emphasize mitigating climate change impacts on transport infrastructure and port operation rather than taking adaptation measures (Ng et al., 2013a). This is unfortunately because proactive adaptation to minimize vulnerabilities is far more cost-effective than mitigation or reactive strategies (Pielke, 2007; Stern and Britain 2006), and also because there are more anticipated regulations or global attention to CO2 issues (Becker et al., 2012).

Since mitigation strategies fail to address all the deleterious risks in the past decades (Applegate, 2010) and are already too late to avoid all deleterious impacts nowadays, especially the potential uncertainties of climate change, adaptation strategies have been put forward and applied to some case studies (Ng., 2013b). The port of San Diego (California) is a good example, sharing responsibility for emergency response, critical utilities protection, and storm water drainage in a community of multi-stakeholders. “The Climate Mitigation and Adaptation Plan” was a pioneering attempt in risk management for properties that serve a common function, developing a risk evaluation framework that considered the likelihood and consequence of impacts and prioritized them by level of risks (Port of San Diego, 2013 as cited by Becker et al., 2013; Messner and Moran 2013). Also, in Australia, the National Climate Change Adaptation Research Facility and the RMIT University constructed a framework for the research of risk, vulnerability and resilience of the country's ports. This plan stressed that port adaptation to climate change involves the development of practices in a range of areas, including planning, insurance, technology and engineering, design and maintenance, and systems management (McEvoy et al., 2013; McEvoy and Mullett, 2013).

Despite all these pioneering attempts, adaptation strategies are still scarce (Ng, 2012). The existing adaptation strategies tend to be limited in coping with specific engineering and technical issues (i.e., dykes, levees, elevation) (Ng., 2013b). Preston et al. (2011) also pointed out that one of main shortcomings of adaptation strategies is overlooking non-climatic elements and issues of adaptive capacity; adaptation plans place priority in investing low-risk capacity building. Likewise, in the context of the United Nations Framework Convention on Climate Change (UNFCCC), initial actions in adaptively addressing climate change impacts mainly focus on capacity building and information exchange (Linnerooth-bayer and Mechler, 2006). At the same time, Osthorst and Manz (2012) suggested that implementing adaptation strategies usually fails to cope with sustainability issues in regional port construction and lack of sufficient supports from high level. Therefore, further research in adaptation strategies calls for planners to devise a regionally oriented plan to cater to the variety of conditions facing ports at a broader level, and shift their attention from physical layout and engineering projects to proactive and strategic planning and management (Ng et al., 2013a). Most importantly, it is necessary for ports to get access to more support from local institutions, federal government and international society and to develop a sustainable adaptation port planning based on the regional reality.

2.1.3 Port planning for climate change

Another issue is that current port planning could not address climate change impacts adequately. The first problem is that relatively short planning cycles (typically 5-10 years) do not match infrastructure lifespans (typically more than 50 years), which leads to greater complexity in planning (ICFI, 2008; Kintisch, 2008; Ng, 2012). Becker et al (2012) found that more than half of the responding ports planned for the historic 100-year storm period, but this preparation will not be effective if the 100-year return period becomes a new 30-year return period due to climate change. With typical port infrastructure designed to last for 50 years or more, new infrastructure put in place today should be built with a new climate regime in mind. Therefore, balancing the investments in infrastructure with the planning cycle, especially under financial constraints, should be considered for adaptation planning.

Meanwhile, as the report from the U.S. National Academy of Sciences stated, “The parameters of the new climate regime cannot be envisioned from past experience…. Decision makers will need new kinds of information and new ways of thinking and learning to function effectively in a changing climate....” (NRC, 2009, pp.1). Scientific information inadequately matches shorter-range planning horizons in port communities (Becker et al, 2012). Nowadays, information for decision making mainly depends on global models with “low spatial-temporal resolution” and “sparse ground-truth ”whose uncertainty is compounded by the expected regional instabilities in extreme events (IPCC, 2012, pp.90).

The complexity of these issues requires a broader collaboration between ports and scientific community to provide precise data for port planning, in addition to refinement of projections and risk-assessment based on targeted port case studies (Becker et al, 2013).

Furthermore, the lack of engineering and design standards to guide decision-making is another barrier for port planners. Taking SLR as an example, the assumption that sea level will rise 1.9 meters by 2100 would result in inundation among a great number of ports. Becker et al (2013) offered three available alternatives: update storm defenses, elevate to compensate for projected sea levels or relocate entirely and pointed out their respective weaknesses. Hard coastal defenses need high capital investments and would lead to environmental problems (e.g., coastal erosion and habitat degradation) (Airoldi et al., 2005); port relocation requires a suitable alternative location, including deep water and transportation linkages. Thus, financial constraints, the appropriate time for construction and other factors should be taken account into strategic planning based on the specific conditions of individual ports.

An instructive guideline and industrial standard are believed to facilitate the progress of port planning by considering climate change impacts. AAPA (American Association of Port Authorities) and IAPH (The International Association of Ports and Harbors) have sponsored workshops to facilitate proactive measures among their member ports. For instance, the "Climate Change Workshop" held by AAPA in 2008 focused on minimizing greenhouse emissions and new regulations, and the WPCI (World Port Climate Initiative) held by IAPH in 2011 provided advanced experiences in sharing information and reaching consensuses on relevant standards and regulation (Becker et al, 2012). Nevertheless, the uncertainties, extensiveness and complexities of climate change issues call for a broader international cooperation and assistance. It means that ports should be regarded as actors in a port supply chain rather than autonomous bodies and should consider the common interests of eve all stakeholders and society at large: developed countries that have higher adaptive capacity are encouraged to assist developing countries with related technology and funding; higher-income countries who have developed more climate policies are encouraged to share climate planning tools and knowledge with lower-income countries; organization represented by AAPA and IAPH are responsible for facilitating cooperation and sharing knowledge in adaptation strategies among worldwide ports (Becker et al, 2012).

2.1.4 Adaptation strategies and planning for climate change

When it comes to near-term and long-range planning, adaptation requires planners consider “soft” interventions before “hard” interventions (Becker et al, 2013, pp.1). As mentioned above, the existing protective measures are often constrained by physical and technical issues of engineering projects, infrastructure and operations, which can be categorized as “hard” interventions. The “soft” measures involve systematic and strategic management planning instruments, such as “land use management, financial incentives, evacuation schemes and institutional changes”(Becker et al, 2013, pp.8; Ng et al., 2013c). By factoring potential climate-related elements into planning at an early stage, “soft” measures will contribute to the proactive reduction of the uncertainties and wastes in the high capital investment engineering works in the future.

One crucial “soft” measure is utilizing insurance instruments for facilitating adaptation strategies to cope with the impacts posed by climate change. Several research studies have been conducted and highlighted the significant role of insurance sectors in adapting to climate change impacts. For instance, Botzen and Van Den Bergh (2008) analyzed the interrelationship between the insurance sector and climate change and elaborated on the effects of private insurance in addressing climate change and flooding risks in the Netherlands (i.e., spread and segregate risks, stimulate loss-reducing incentives). In comparison with the insurance arrangements in the United Kingdom, Germany and France, they suggested that partial private insurance arrangement could effectively overcome the problem in private insurance, including difficulties in assessing risks and uncertainties, adverse selection and moral hazards of information asymmetries and correlated risks between insurance companies and policyholders, etc. Meanwhile, they also encouraged an active role for government to overcome capital shortage in private insurance schemes and to build public-private partnership in multilayered insurance programs.

Linnerooth-bayer and Mechler (2006) stressed that developed countries should bear more responsibility for adapting to climate change in developing countries, and provide a two-tier climate insurance strategy for supporting developing countries to adapt to climate change. This strategy would involve establishing insurance programs, institutional forms and providing disaster relief contingency to manage climate-related risks in developing countries. This research was also consistent with the results of the Becker’s survey (Becker et al., 2012) that ports located in high-income nations carried more insurances compared with upper and upper-middle and low-income nations. Therefore, the ports in Canada (and in other developed and high-income countries) are expected to place more attentions on the role of the insurance sector, not only in establishing resilient adaptation strategies for coping with climate change impacts on their own ports planning, but also in assisting developing and low-income countries address climate change issues.

Despite such abundance, the existing research on the insurance sector's role rarely focuses on the specific port or transport-related area. Thus, research on how the insurance sector could relieve the climate change impacts on the ports industry will be beneficial to port adaptation planning. At the same time, Becker et al (2012) argued that more complicated questions need to be considered: for instance, how to select and manage insurance for the different stakeholders in port supply chains according to a wide range insurance policies; how to adjust the shift the role of the insurance industry from a passive to a proactive one; and how could insurers and reinsurers could encourage risk-reducing strategies before climate change happen.

92% of ports in the global survey (Becker et al., 2012) being either public or public/private owned or operated (owned or operated by government port authorities). With the level of public involvement, it can be assumed that the public interests cannot be neglected in port planning and decision-making. Thus, supplemented with support from the insurance industry, public policy, as another "soft" intervention in adaptation planning, should play a crucial role in relieving climate change risks on ports and uncertainties on the environment and port-dependent economy. He recommended that, for policy makers, new policies require ports to "enhance resilience by engineering protective structures, elevating storage of pollutants, or simply creating better storm preparation strategies (pp.22)" at the local level, and require funding to assist decision making, setback regulation, standard designing and insurance management at the national level.

Nowadays, a relatively mature adaptation framework for climate change impacts has been developed. For instance, "Adaptation Policy Frameworks (APF) for Climate Change: Developing Strategies, Policies and Measures" developed by NCSP (the National Communications Support Unit of the United Nations Development Programme)(Burton and Development Programme United Nations, 2005). The APF is composed of a User' s Guidebook and nine Technical Papers *(1. Scoping and Designing an Adaptation Project; 2.Engaging Stakeholders in the Adaptation Process; 3. Assessing Vulnerability for Climate Adaptation; 4. Assessing Current Climate Risks; 5. Assessing Future Climate Risk; 6. Assessing Current and Changing Socio-economic Conditions; 7. Assessing and Enhancing Adaptive Capacity; 8. Formulating an Adaptation Strategy; 9. Continuing the Adaptation Process).* This framework provides policy makers with a systematic approach for dealing with climate change impacts in different regions of the world. The highlighted context and principles (i.e., in adaptation strategies, process making, public participation) also can be applied to adaptation port planning. However, how to adjust to the specific environment in different ports and risk conditions is a challenging question for the port policy maker and stakeholders.

Another consideration is that policy-making is a complicated process, which cannot be regarded as synonymous with planning (Everett, 2005). In particular, when policy-making is related to port and transport planning which involve multiple networks in port supply chains and benefits of stakeholders, the policy making process often ends in failure due to the inappropriate planning in the initial stage. As Lindblom (1959) and Colebatch (2002) suggested, the policy decision is determined by a variety of participants who play a key role in horizontal planning, instead of government and industrial leaders and senior managers alone. It means that port and transport planning, can be regarded as a fundamental part in public policy. Correspondingly, the policy-making process calls for decision makers to incorporate public and pressure groups' interests, and political and other social, economic and environmental elements into the initial port planning. As climate change is one of the significant factors in environmental and economic construction, it is strongly recommended to emphasize the climate change impacts in public policy making and encourage the diverse participation in adaptation port planning.

2.1.5 Adaptation planning for climate change and dry port

The first mention of dry ports concepts in academic literature can be traced back to 1980 (Munford, 1980). Admittedly that there is no clear consensus on the definition of dry ports; it could generally synonymous with inland terminals (UNCTAD, 1982, pp.viii), which could be defined as locations "to which shipping companies issue their own import bills of lading for import cargoes assuming full responsibility of costs and conditions and from which shipping companies issue their own bills of lading for export cargoes"(UNCTAD, 1982, pp.2). A recent definition of dry port was proposed by Roso (2007, pp.523): "an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardized units as if directly to a seaport". In this thesis, following a relatively complete definition, dry ports can be regarded as a distribution center where freight (de-) consolidation takes place with functions that are similar to those of seaports, including cargo handling, providing intermodal transport connections, information exchange and other value-added services such as custom clearance, inspections, storage, maintenance and repair of empty containers, and tax payments (Beresford and Dubey, 1990; United Nations Economic Commission for Europe (UNECE, 2001).

Although the concept of dry ports was put forward only in the recent three decades, there has been a considerable amount academic research on dry port, which has been applied to practices and resulted in and achieved practical attempts from both international and regional perspectives. A majority of relevant articles involves the discussion about the significance and advantages of dry ports (i.e., Roso and Lumsden, 2010; UNCTAD, 1991). Generally, the development of dry ports is beneficial to increase coastal port capacity and productivity, while reducing transport costs, traffic congestion, air pollution and accidents (Rahimi et al., 2008; Roso, 2007; Roso, 2008; Wang and Wei 2008).

Roso and Lumsden (2010) did a relatively extensive literature survey on the existing dry ports and clarified the concept of dry ports and the discrepancies or agreement between theory and practice, and identified several qualitative criteria for the development of dry ports. *Handbook on the Management and Operation of Dry Ports* (UNCTAD, 1991) provided a planning guide for universal application of the general procedures involved in the establishment of dry port, typical characteristics of dry ports and their benefits, as well as suggestions in administration and management structure of dry ports.

At the same time, the studies for certain regions or individual dry ports have resulted in prosperous development (i.e., Rodrigue and Notteboom, 2012; Henttu and Hilmola, 2011; Ng et al., 2013d). For instance, Rodrigue and Notteboom (2012) compared the setting and development of rail-based dry ports in Europe and North America. They investigated the similarities in dry ports' development in two areas including "the types and strategies of stakeholders involved in, the dynamics in logistics network configurations, the specific competitive setting" etc. (pp.1). Meanwhile, they pointed out the discrepancies in the two regions. For example, in North America, the decision making of the setting of a dry port is mainly depended on market potential and the overall impacts on the network structure. Whereas in Finland, Henttu and Hilmola (2011) focused on the financial and environmental impacts of hypothetical Finnish dry port structure by utilizing analytical models to examine the feasibility of dry port concept in the Finnish transportation network. They concluded that the establishment of dry port in Finland is conducive to reducing the transportation costs and make up the deficiency of seaport that restricted by sulfur emission reduction regulation. Ng et al (2013d) investigated the institutions, bureaucratic and logistical roles of dry ports in Brazil and emphasized the significant effect of a dry port, as a node along the supply chain, in providing services for cargo flow with the advantages of cost reduction and environmental contribution.

Despite such abundance, it is evident that the current research in the field of dry port tends to be concerned with their favorable influences (e.g., in strengthening seaport efficiency, competing with seaports and minimizing congestion and pollution) (Ng et al., 2013d). The studies in dry port are relatively scattered and tend to underestimate some potential risks and uncertainties in port operation and planning. One of the most important factors is the impact of climate change on dry ports.

First, climate change is a critical issue in guaranteeing the security of a dry port. Chandrakant (2011) proposed that container security and environmental impacts are associated with the overall efficiency of a dry port. In this article, through a new eco-DEA model, Chandrakant concluded that the efficiency assessments of a dry port have dramatic changed when environmental factors are taken account in the model. Meanwhile, considering the container security at a dry port, Chandrakant suggested that further studies investigate other unquantifiable factors and put dry ports into a complex system with an increasingly competitive atmosphere. It is obvious that climate change is highly related to the environmental impacts, as well as container security by posing risks or uncertainties (as unquantifiable factors) on a dry port, so as to influence the efficiency of a dry port. Likewise, Roso and Lumsden (2010) emphasized the importance of security at a dry port especially in customer clearance. The International Ship and Port Facility Security (ISPS) code required port planners consider the changes in the physical design, adjoining facilities and general port activities (Mazaheri and Ekwall, 2009), while all of the above aspects are vulnerable to the climate change.

Second, an adaptive plan on dry port by considering climate change impacts is consistent with the demand for a long-term viability of a dry port. Ng et al (2013d) summarized three core attributes determining the sustainability of a dry port, and one of capacities is integrating with seaports and shipping lines. Owing to the recognition of the significant effect of dry port in connecting seaports and the important role in port supply chain, the risks of climate change on seaports would penetrate on dry ports and generate indirect impacts or uncertainties. As it recommended (Ng et al, 2013d), further studies need to understand the impacts of geographical context (i.e., climate change) and network formation under the deficient infrastructure and planning.

Third, adaptive dry port planning, by considering the risks and uncertainties posed by climate change, has more natural advantages than adaptive seaport planning. It partially stems from the fact that dry ports are usually geographically far away from storm-impacts. In addition, the development of dry ports contributes to the environment-friendly environment. A dry port is able to decrease CO_2 by 25%, which is attributable to the fact that road transportation is substituted with rail transport which has a smaller relative carbon footprint (Beresford and Dubey, 1990; Roso, 2009a; Roso, 2009b).

However, since most of the focus of the risks of climate change is on seaports, rather than on dry ports (e.g., CentrePort Canada) until now, there has been very limited research examining the potential risks or uncertainties of climate change on dry ports. Understanding such, this thesis initially classifies the impacts on dry ports into extreme weather, flooding, precipitation change and landslide, which will be further discussed in the following chapters by a survey and two case studies.

2.1.6 Climate Change and port adaptation planning in Canada

The Canada Country Study: Climate Change and Adaptation: National Sectoral Volume (Yoshida and Avis, 1998) comprehensively illustrated the climate change impacts in Canada and corresponding adaptation measures to cope with it. Since ports are always regarded as a crucial node in transportation system, the impact of climate change on transportation sector could reflect some main issues in port industry.

The Volume of Transportation Sector in this study (Yoshida and Avis, 1998) elaborated on the three primary research directions in exiting research: shipping in the Great Lakes - St. Lawrence River system, coastal infrastructure, and northern roads. All the activities in the three areas has negatively and directly influenced by climate change. For instance, the considerable impacts of climate change on Great Lakes international shipping are examined in Millerd's study (Millerd, 2011). With the higher temperatures leading to the lower water level in the Great Lakes area, the vessel drafts and the number of cargoes will be restrained, which further causes higher costs in cargo moving and port operation. The potential impact of climate change is that a shorter season of ice cover will lead to an extended navigation season in the Great Lakes area. However, seaway and lock managers have no adequate plans to guard this change. In coastal regions, especially in Atlantic Canada, sea-level rise would reach billions of dollars of damage to road, rail and port infrastructure. In northern regions, such as the Mackenzie Basin, changes in temperature and/or precipitation would reduce the length of the ice-road season, raising the costs of winter transportation (Yoshida and Avis, 1998). On the other hand, however, both road and coastal operations would benefit from climate change due to a shorter winter season, deeper drafts and decreased ice cover. It is obvious that all the impacts of climate change in transportation are highly associated with the port operation in an either a negative or positive way. Moreover, some potential vulnerabilities and uncertainties from climate change also indirectly impact on transportation and port development. Although there is lacking sufficient research to demonstrate the indirect impacts statement, the changes of transportation and port infrastructure activities through the impacts of climate change in climate-related fields are substantial with the invariability of demand in the port supply chain. The IPCC report (Moreno et al., 1996) provides a framework by considering the indirect impacts of climate change on transportation. Climate change, by affecting fossil fuel use, agriculture production, tourism and regional growth to commodity flows, passenger flows and distribution of economic activity and population, would lead to substantial capital and operating costs in port infrastructure and activities.

Canadian transport (including port) industries, government, organization and public have invested a great amount of money (hundreds of millions of dollars) to minimize the impacts of climate change (Herbert and Burton, 1994). At the same time, relevant adaptation attempts have been conducted to cope with the risks of climate change, such as the studies of meteorological prediction and assessment on transportation infrastructure and operations (e.g., Perry and Symons, 1991; Thornes, 1992). Nevertheless, as this study (Yoshida and Avis, 1998) pointed out in the end, there remain a few limitations in adapting to weather and climate change on transportation sector in Canada. At least three aspects need to be considered. First, despite upgrading awareness and investment in adaptation strategies (e.g., prediction for climate change impacts on transport operation and infrastructure)(e.g., Perry and Symons, 1991; Thornes, 1992), there is insufficient research associated with the exact costs and benefits on Canadian transportation. Second, design, construction and maintenance in port construction are sensitive to the weather and climate change, which needs to be considered on the initial planning stage. Third, the effectiveness of many adaptation measures against climate change are rarely measurable, especially when involving indirectly impacts and individual port conditions (Yoshida and Avis, 1998). Apart from the three aspects mentioned above, but for the port sector itself, there are the interdisciplinary characteristics of the impacts of climate change on ports. It might suspect that the research in transport sector was constrained and should be extended to related sectors such as hydrology, fishing, built environment.

2.2 Theoretical Framework

2.2.1 Path dependence theory

“Path dependence implies that prior conditions and events constrain and shape later outcomes and policy options” (Van Driel and Devos, 2007, pp.682). This concept emphasizes the uncertainties in a process that the original form of phenomenon is impacted by “initial conditions” and the development of subsequent form restricted by “lock-in” effects (Van Driel and Devos, 2007, pp.682).

Path dependence is usually regarded as a vital theory in strategic planning and action. The basic point of path dependence in strategy research is that processes are not only contingent on the context where they occur, but also on their own histories (Arthur et al., 1987). One of critical implementations to the strategy process is that past decisions influence decisions in the future (David, 1990). Also, a small event could (result in huge changes from the perspective of strategic management) (Stacey, 1995; Stacey, 1996). Reflecting to the impacts of climate change on ports, there is little doubt that the past events’ occurrence of climate change at a port (i.e., the frequency, severity, costs) will affect the decision making in a port planning. At the same time, the assumption that even a small event will trigger a change in strategic planning motivates planners to pay more attention to potential events and uncertainties posed by climate change. In other words, path dependence theory, as a creator of strategic possibilities, suggests that an adaption port plan which considers the possibilities of potential uncertainties will be advantageous to the actions and interventions for climate change impacts in the future.

Gáspár (2011) developed the concept of path dependence by combining it with path creation from a strategic perspective. Gáspár argued that the two concepts are not alternatives but closely connected with each other. Specifically, both path dependence and path creation link the present with past and future. In Gáspár's model, decision-making is determined by a "statistical sense (historical matters)" and "chaos theory (small change matters)"(pp.95). This concept implies that the decision making for the future not only relies on the historical events but also "hopes, fears or expectation"(pp.95). Correspondingly, the interaction with the external environment and the future also improves the current decision and past experience in the long term. On the basis of Gáspár's article, it can be inferred that the motivations of an adaptation port plan stem from two factors: the historical climate change event or small changes, and the prediction for climate change in the future. More importantly, a favorable adaptation port plan might also modify the existing port planning and operation and provide valuable experiences for other ports.

The concept of path dependence theory has been applied to seaport studies in diverse way (Notteboom et al., 2013). Specifically, there are three main streams dealing with the evolution of path dependence at sea ports. The first one is the long-term evolution of port systems (Bird, 1973), which focuses on the changing relationship between the port and the port city (Hoyle, 1989; Norcliffe et al., 1996). The second stream is the governance systems of ports (Brooks and Cullinane, 2007), which regards seaports as agglomerations of relevant industries and concerned with the unique development trajectories of ports and the diversity of management structures (De Langen and Chouly, 2004). The last stream emphasizes the role of path dependence in institutional economics and geography and place, which implies the differences of institutional path dependence with the change in ways and places. As

Notteboom et al (2013) suggested, all the above three streams involves the dynamic interaction among institutional environment, government structure and the landlord port authority. With the impacts and uncertainties of climate change being increasingly serious and unpredictable, the development and evolution of ports require planners to consider the dynamics and stability in institutional economics, governmence system and geographical conditions. Thus, an adaptation port plan by considering the potential risks and uncertainties is a positive response to the path dependence theory in ports. Also, as Shou (2011) mentioned that every path dependence system has evolved as the result of different histories of their systems, and owing to the disproportionate impacts of climate change in different geographical areas, planners are required to consider the specific conditions at every individual port. Moreover, it is noticeable that it is a chronological process that the decisions at an initial stage will affect the consequence of events in the later stage in the future (Pettigrew, 1992). This opinion encourages planners to consider the sequences of events' occurrence and improve the elements in climate change when making an adaptation port plan.

Meanwhile, path dependence theory has also been applied in studies of long-term strategic port planning (Dooms et al., 2013) although in a limited way. Pierson (2000) and Kay (2005) suggested that the concept of path dependence is related to analysis of temporal dynamics, which emphasizes that significant changes in investment strategy and governance are often attributed to the shift of exogenous events (such as climate change impacts) and role of stakeholders. Since decision-making is a multi-party involved process, path dependence indicates that particular institutions in the path could be substituted when the existing institutions and conditions cannot approach the objective (Shou, 2011). Therefore, a long-term, strategic plan based on real stakeholder inclusion can play an important role in governance change and development (Dooms et al., 2013). In other words, to establish a resilient framework for ports' adaptation planning to minimize climate change risks and impacts, port authorities should take into account uncertainties of climate change and its impacts on ports' stakeholders.

2.2.2 Stakeholder management theory

Stakeholder theory originated from the field of strategy, and the stakeholder is defined as "any group or individual who can affect or is affected by the achievement of the organization's objective" (Freemen, 1984, pp.53). 'The stakeholder theory is "managerial" and recommends the attitudes, structures, and practices that, taken together constitute a stakeholder management philosophy' (Donaldson and Preston, 1995, pp.67).

Smudde and Courtright (2011) did holistic research in stakeholder management based on three primary questions: "(1) how are stakeholders created? (2) how can relationships with stakeholders be maintained? (3) how can relationships with stakeholders be improved?" (pp.137). Meanwhile, in response to the demand of strategic planning, two realms of stakeholder management have been elaborated in Smudde and Courtright's article to enhance the dynamics of this field: reactive and proactive stakeholder management. Specifically, reactive stakeholder management focuses on past activities that have affected relationships with stakeholders. By a single-loop learning process, reactive stakeholder management highlights the need to draw past experiences including what went right and wrong, what deficiencies were eliminated or reduced, and what could be improved in the future, etc. Proactive stakeholder management is concerned with future activities in order to produce opportunities for cooperation between any stakeholders and the organization. The proactive concept involves a double-loop learning process where an organization is adaptively adjusting to the management process in a changeable environment. The advantage of proactive stakeholder management relies that, via an adaptive and tactics design, it would maximize (or enhance) the strengths, minimize the weakness, generate opportunities and screen threats for success in the future. Accordingly, adaptation port planning against climate change impacts is consistent with proactive stakeholder management theory in predicting the potential damages, crises and disasters, managing the relevant personals who are and will be stakeholders and improving the stakeholder relationships.

Fassin (2012) analyzed strategy management, reciprocity and responsibility. Stakeholders can be broken down to the four categories in terms of their legitimacy: stakeowners, who are the internal constituents having a real stake in the company; stakewatchers, who are the mainly pressure groups influencing the firm; stakekeepers, who are the mainly regulators imposing external control and regulations on the firm; and stakeseekers, who are seeking a voice in a corporation’s decision making (Holzer, 2008). While stakeholder theory has mainly focused on corporate responsibility towards a firm’s stakeholders (i.e., Friedman and Miles, 2006; Freeman et al., 2007) from the strategic perspective, Fassin (2012) proposed that stakeholders could also influence the corporation (stakeholder reciprocity and responsibility). More specifically, the stakeholder reciprocity could be limited by the stakeowners who are legislated stakes and loyal partners involving multiple benefits; meanwhile, the stakeholder in stakeholder responsibility refers to the corporate stakeholders excluded from the stakeowners. To construct a long-term commitment and responsibility requires paying more attention to the reciprocity from stakeoners and their moral responsibility including loyalty, fairness and ethical treatment. At the same time, stakewatchers and stakeseekers formulated their strategy from the political resources perspective should not underestimate their ethical responsibility. Applied to the port industry, planners are encouraged to recognize the diverse roles in stakeholder's networks, and be concerned with the reciprocity of stakeonwers and responsibility of different corporate stakeholders when making an adaptation port plan.

Existing literature has, to date, provided applicable guidance for stakeholder management in port governance and planning. First, stakeholder management reflects the demand of increasingly intensive competition and integration of multimodal port supply chains (Lam et al., 2013). Port supply chains imply that "the port as its core enterprise, combines and coordinates its service providers (i.e., transportation, handling, inventory) with customers (i.e., shippers, shipping companies) into a system effectively, distributes the correct number of goods to the right place at the right time " to maximize the efficiency and profits of entire supply chain (Cheng and Zhu, 2011, pp.1). This requires a comprehensive stakeholder management process where port planners emphasize the role, responsibility and relevance of stakeholders, and consider both internal and external uncertainties in port supply chains. As Dooms et al (2013) pointed out the divergent preferences of stakeholders for the desirability of further port development, how to balance the multiple benefits of port stakeholders in port supply chain is another question which needs to be thought nowadays. Therefore, a long-term, strategic port plan based on stakeholder management would contribute to change in the broader port region and port supply chains.

Second, stakeholder management contributes to the regional port governance. Port stakeholders, involving shipping companies, shippers, terminal operators, government, logistics service providers and other parties associated with port industries, are expected to create and sustain value in the same customer value chain (i.e., Debrie et al., 2013; Lam et al., 2013). Particularly, the regional port governance broadens the scope of stakeholders to policymakers at diverse levels, community groups and market players at diverse ports (Preston and Sapienza, 1991). The complexity of stakeholder management in port regional governance calls for the collaboration of multiple parties through joint projects and technological innovation which is supported by a strategic port planning of policymakers, so as to minimize the conflicts among stakeholders and maximize their common benefits (Lam et al., 2013). This theory can be also applied into adaptation port planning. In response to the increasing risks and uncertainties of climate change on ports in a wider area, port planning is expected to accommodate the change of the external environment, encourage a extensive participation of stakeholders, reduce the risks and conflict among the port stakeholders, create a technology framework and tailor to the specific port conditions by a joint effort against to climate change.

2.2.3 Supply chain risk management

With the topic of supply chain management and risk management each having been established and developed, their intersection area, supply chain risk management (SCRM), the definition attention in the past decades (Paulsson, 2004). Although there is a variety of definition of SCRM, it is mainly related to the concept of risk and uncertainty in supply chains. One definition suggested by Paulsson (2004) (as cited Norman and Lindroth, 2002, pp.7), is “Supply chain risk management is to, collaboratively with partners in a supply chain or on your own, apply risks management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources in the supply chain.” In the context of SCRM, risk can be regarded as “unreliable and uncertain resources resulting in supply chain interruption”, while uncertainty can be interpreted as “matching risk between supply and demand in supply chain processes” (Tang and Musa, 2011, pp.26). It is acknowledged that both of the risks and uncertainties in SCRM are usually related to negative consequences and difficult to distinguish in the most of literature (e.g., Christopher and Lee, 2004, Paulson, 2005, Spekman and Davis, 2004, Wagner and Bode, 2006).

Tang and Musa (2011) defined supply chain risk following two conditions: “(i) events with small probability but may occur abruptly and (ii) these events bring substantial negative consequences to the system”(pp. 26). Meanwhile, since risks in supply chain are associated with the chance of happened (“hazard occurring”) (Brindley, 2004), as well as the consequences of these events (The Royal Society, 1992), as Brindley (2004) interpreted from a quantitative perspective, Supply Chain Risk = Probability (of an event) * Business Impact (or severity) of the event related to the chance. More recently, with the design objective of supply chain extending to supply risk, security and sustainability, supply chain risks is also can be interpreted as “the extent to which supply chain outcomes are variable or are susceptible to disruption, and, thus, may be detrimental to a supply chain” (Zsidisin et al., 2005, pp.3403).

There are considerable studies investigating the type of supply chain risks. Generally, supply chain risks contains supply breakdowns, disruption, purchasing and forecasting failures (Chopra and Sodhi, 2004; Harland et al., 2003; Johnson, 2001; Spekman and Davis, 2004; Zsidisin, 2003). Supply chain disruption as one of major risks, can be divided into two categorizations: unintentional and intentional disruptions. Unintentional disruption includes natural disasters (e.g., hurricanes, tornados, floods that might disrupt supply paths, transportation and manufacturing infrastructures) as well as man-made accident (e.g., transportation related injuries that might lead to transportation delays, and further negative effects on products and services)(Speier et al., 2011).

Tang and Musa (2011) categorized the risks in supply chain by material flow risks, financial flow risks and information flow risks in a literature survey form 1995 to 2008. The risks in material flow stem from source, make and delivery aspects and represented by variables in sourcing flexibility, suppler selection, product monitoring, product process and design, demand seasonality (i.e., Fitzgerald, 2005; Christopher and Peck, 2004; Handfield et al., 1999; Khan et al., 2008; Peck, 2005; Bovet, 2006). In financial flow, the risks come from unstable factors in exchange rate, price and cost, financial strength of supply chain partners and financial handling and practice (i.e., Johnson, 2001; Bovet, 2006; Hartley-Urquhart, 2006). Also, in information flow, the risks include information accuracy, information system security and disruption (i.e., Lee, 2004; Finch, 2004).

Meanwhile, as the increasing changes in the market and the long-term consideration of strategic decisions in supply chain network design (Baghalian et al., 2013), it is noticeable that uncertainty is playing an increasingly important role in supply chain management. Up to date, there has some attentions on lower-impact and unintentional risks, which involves the risks and uncertainties posed by climate change in supply chains to some extent. SCRM, as a major part of SC management, requires designing a dynamic SC network structure by considering both risks and uncertainties in order to manage the product flow throughout the system to predict, arrange and recover from disruptions (Baghalian et al., 2013). Therefore, a long-term adaptation plan for climate change will be contribute to minimize the risks and uncertainties and increase the dynamics in SCRM.

A literature survey on SCRM from 1995-2009 (Tang and Musa, 2011) demonstrated that there have been a growing number of publications since 2004 with continual attention from both academia and industries. At the same time, frequent discussion topics include challenges and opportunities of outsourcing to low cost countries, information security and sharing, partner relationship, economy, environmental and political issues in supply chain etc. Nevertheless, there are some gaps in SCRM research. Although some efforts have been extended to combine material and cash flows, a majority of literature still relies on the issues in material flow, especially in supplier selection. Also, even though enough awareness has been given to SCRM in industry, the main focus still relies on qualitative aspects (e.g., descriptive and conceptual models) and there is a lack of quantitative research (e.g., quantitative model, risk-related information). Based on this result, some potential approaches in developing quantitative models have been proposed including robust planning, system dynamics, reverse logistics etc. This enlightens the author to establish an adaptation plan for risks and uncertainties posed by climate change by combining qualitative and quantitative methods.

Although there is widespread recognition that a port is a key node in a supply chain, and supply chain management should be applied to the port sector, port risk management has not been given sufficient attention. Current research in supply chain risk management tends to focus on identification of disruptions and mitigation countermeasure for catastrophic events (i.e., Guerrero et al., 2008). Meanwhile, researchers tend to be concerned with risk factors in the change of demand and marketplace in supply chains (e.g., Das, 2011). However, given the fragility and complexity of port supply chains, adaption planning by considering uncertainties in climate change should be applied in port risk management.

2.3 Hypotheses

Based on the primary research questions, objectives, and the literature review above, this thesis proposes the following three hypotheses in order to investigate two secondary research questions: 1) How effectively do adaptation measures address climate change impacts? 2) What are the differences or similarities of climate change impacts on Canadian ports (seaports and dry ports)?

Hypothesis 1: Adaptation strategies minimize the existing impacts of climate change on ports: there are fewer impacts of climate change on a port if an adaptation measure has been implemented than the impacts on a port if adaptation measures have not been implemented in the past decade.

Hypothesis 2: Adaptation measures and the existing impacts of the climate change on ports are positively relevant: there are more adaptation measures are implemented if there have been more risks and uncertainties on ports posed by climate change in the past decade.

Hypothesis 3: There are different impacts of climate change on seaports and dry ports: there are fewer impacts of climate change on a dry port than on a seaport in the past decade.

Besides the above hypotheses, this thesis also discusses other relevant issues based on the results of a nation-wide survey (Chapter 4). For instance, the most concerning climate risks and uncertainties on ports, the perceptions of respondents on adaptation strategies in the future, the time horizon of an adaptation plan for climate change, etc.

2.4 Propositions

Simultaneously, this thesis proposes the following two assumptions so as to investigate another two issues in adapting to climate change: 1) How is an adaptation plan for climate change impacts on ports generated? (What is the process of adaptation planning?) 2) How to implement an effective adaptation plan? (What are important factors in an adaptation plan?).

Proposition 1: There lack of a uniform process of adaption planning for climate change impacts in different ports; an instructive guideline and industrial standard would contribute to improving the efficiency of adaptation planning.

Proposition 2: There are trade-offs among different parties in implementing an adaptation plan; a successful adaptation plan for climate change impacts requires a broad and balanced collaboration between internal and external port stakeholders in the port supply chain.

Apart from the above propositions, this thesis will also discuss other relevant issues. For instance, the perceptions of interviewees on mitigation and adaptation strategies in port planning, the main priorities and low priorities in adaptation planning, the references in planning and public participations in implementing adaptation planning, etc. Via a series of interviews under the two case studies (Chapters 5 and 6), this thesis attempt to explore these questions and offer further suggestions for adaptation planning.

Chapter Three: Methodology

3.1 Introduction and Related Background

This thesis employs two main methods: survey and case study.

This survey aims to examine the perception of port planners and stakeholders of climate change impacts, current measures and future planning on their ports, in order to illustrate the general situation of this topic among Canadian ports and further justify the necessity of adaptation strategies and planning. A sample of 26 port administrators representing 21 Canadian ports (e.g., Montreal, CentrePort, Churchill, Halifax, and Sydney (NS)) were selected to assess the perception of port planners and stakeholders of climate change risks, including perception for general climate change risks and specific impacts on their port operation, performance, facilities, and infrastructure. The survey also involved questions concerning current and long-term port planning by considering climate change risks and uncertainties and how strategic adaptation planning would impact the efficiency of port supply chains.

Meanwhile, this thesis included two in-depth case studies. One is the port of Montreal, and the other involves CentrePort and Hudson Bay railway as a port supply chain. Semi-structured, in-depth interviews have been undertaken with relevant personnel. The interview questions were expected to investigate some “hidden” problems, which are hard-to-reach through the previous survey. For instance, understanding the planning process and crucial elements in current and future adaptation port planning.

At least three relevant surveys have been conducted from regional and global perspectives (Becker et al., 2011). In 2005 and 2006, a group from Texas A&M University conducted a survey entitled “Port Planning and Views on Climate Change”, which mainly focused on the question: “is planning for climate change on the radar screen of the USA seaport industry” by sampling 27 seaports in the USA (Becker et al., 2011, pp.10). The results demonstrated that, although many respondents have realized the impacts of climate change on their ports, few respondents have adequate measures, or even initial steps on plans (Bierling and Lorented, 2008). Similarly, even in California, one the most progressive states of the US, two related surveys indicated that the expected risks of climate change and SLR on maritime facilities were generally ignored, while the SLR was anticipated to reach 1.4 meters by 2100 (CSLC, 2009). One of the most important studies is by Becker et. al in 2009. It was a global survey which dealt with knowledge, perceptions, and planning effects among port administrators (Becker et al., 2011) and it summarized several questions about climate change impacts, adaptation strategies and planning on worldwide seaports. For instance, the survey showed that nearly half of the respondents believed climate change would pose negative impacts on their operations in the coming decade, and 66% of respondents felt such directly impacts had not been well informed.

Nevertheless, there has been no specific survey and interview focusing on climate change impacts and adaptation on Canadian ports, especially on dry ports. Owing to the diverse risks and uncertainties of climate change, the complex conditions of port planning, the lack if attention to adaptation strategies, the unique characteristics of seaports and dry ports in Canada, and other invariables explained in above context, there is a very limited databases for this research. Accordingly, this survey and interview collected first-hand primary data to fill the gaps in the field of dry ports, adaptation strategies and planning, as well as regional studies of ports in Canada so as to provide the innovative thinking pattern for global studies.

3.2 Survey

As the distance to tidewater is an important factor in influencing the perceptions of dry port administrators see things differently that seaport administrators (Becker et al. 2012), the ports here were categorized into seaports and dry ports (or inland terminals). This nation-wide online survey was mainly focused on the risks and uncertainties posed by climate change on Canadian ports (seaports and dry ports) and their adaptation strategies and planning. Specifically, this survey has the following objectives:

1) To investigate the effectiveness of adaptation measures, as well as the current situation and differences or similarities of Canadian ports (seaports and dry ports) in implementing adaptation strategies (the three hypotheses);

2) To assess the perception of port planners and stakeholders in Canada on climate change risks and uncertainties, including their perceptions of general climate change impacts and specific impacts on their port operation, performance and infrastructure;

3) To anticipate the potential influences if adaptation measures are conducted in the future in the both seaports and dry ports of Canada;

4) To understand the important aspects and factors in formulating plans for ports to adapt to the risks of climate change.

The population of ports was “those ports that are engaged in facilitating the transport of cargo” (Becker et al., 2011, pp.11). The database of World Port Source lists 239 ports in Canada, and they were shown a global map and this database was used to select the port for this study (World Port Source a n.d.; World Port Source b n.d.). In this survey, small port might lack basic knowledge or experiences for climate change issues and the representativeness of the samples is more important than its generalizability in judgment sampling (Vogt and Gardner 2012)). Considering the uniqueness and complexity of climate change issues (i.e., the differences in ports' characteristics, geographic distribution of seaports and dry ports, and types and levels of risks or uncertainties posed by climate change on ports), non-probability sampling, includes a combination method of judgment sampling and snowball sampling, was utilized in this survey.

There were three criteria for the survey sampling: 1) large and medium sized ports, including the most heavily used largest and most heavily used in the list of World Port Source: 26; 2) ports were added to provide geographical balance because most ports are in the East and West Canada: 5 (Port of Churchill, CentrePort Canada, Iqaluit Harbor, Tuktogaktak Harbor and Nanisvik Harbor); 3) port authority members of Canadian two port associations, namely Association of Canada ports Authorities (ACPA) and Green Marine in Canada: 18. Finally, a sample list containing 28 Canadian ports was generated, deleting overlaps among the four criteria. Based on the 28 samples, snowball sampling was used by inviting one or two relevant personnel (e.g., the port planner) of each port to ask their colleagues (e.g., the port director) to take an online survey. It was anticipated that 3-5 questionnaires would be returned from each port, thereby providing a sufficiently large sample to ensure high quality. However, in the real sampling processes, other ports were added with the assistance of ACPA and Green Marine so as to generate a list containing 30 ports in Canada. The survey was undertaken in July-August 2014 (distributed mainly online through Survey Monkey).

E-mails or phone calls were used to contact all the respondents during business days. At the end, 26 effective responses were received, with a response rate of 86.67%. The questions in the questionnaire were divided into two types: closed-end questions, which utilized multiple choices and a likert-scale approach to quantify responses; open-ended questions, which provided more freedom to respondents and produced richer data. The survey was contained 27 questions and the details can be found in Appendix A.

3.3 Interview

In this thesis, two case studies with three in-depth cases have been undertaken by several interviews. It targets the Port of Montreal in the province of Quebec, as well as CentrePort Canada and Hudson Bay Railway as a port supply chain in the province of Manitoba. These interviews were expected to investigate some “hidden” problems in risk management of the ports in specific regions, which are hard to reach through literature review or survey alone. For instance, understanding the planning process and crucial elements in current and future adaptation port planning for climate change. As the studies focus on the planning process, a qualitative research approach is more relevant, as it is able to access a considerable amount of unpublished, qualitative information, so as to enable researchers to analyze relationships and social process, which it would be difficult to do using only quantitative methods especially when abundant data are lacking. (Miles and Huberman, 1984).

The first part of the research, the findings can be found in Chapter 5, involves two in-depth cases on CentrePort (a dry port/inland terminal) and the Hudson Bay Railway. In 2014, seven semi-structured, in-depth interviews (five face-to-face and two telephone interviews) were completed with relevant personnel affiliated with CentrePort and Hudson

Bay Railway. The second part of the research (in Chapter 6) involved an in-depth case study on the port of Montreal (a seaport) in the province of Quebec, Canada. In 2015, the study completed five semi-structured, in-depth interviews (four face-to-face and one telephone interviews) with relevant personnel affiliated with the port of Montreal. All the interviewees were visited via one or two key informants at each port from the targeted population which includes: CEOs or senior port directors, port planners, environmental managers, development managers, policy makers, environmental academics, port relevant stakeholders, etc. A number of interview questions and basic information of interviewees can be found in Appendix B.

Interviews are a commonly used qualitative method, and were utilized to collect data in the two case studies to reveal other hard to reach planning questions (e.g., the key factors, processes and references in an adaptation plan). The interviews investigated several possible problems in current port plans in Canada so as to highlight the significance of adaptation strategies and their details in implementation. Specifically, the interview addressed the following issues:

1) What are the current climate change risks and uncertainties, and what specific climate change events have impacted, the interviewees' ports in the past decades? Meanwhile, what are the perceptions and considerations of the interviewees in implementing adaptation and mitigation strategies for climate change impacts?

2) What are the main priorities and principles for adaptation planning for climate change in terms of the short-term and long-term planning among the interviewees' port? How does the decision-maker assess the risks or uncertainties posed by climate change?

3) How do the interviewees conceive the unique conditions of their ports' adaptation planning? What kind of resources do they utilize when conducting adaptation planning for climate change?

4) What are the interviewees' perceptions of adaption planning for climate change? Who are the internal and external participants supporting and conducting adaptation planning for climate change?

5) What is the planning horizon of adaptation planning for climate change? What are the primary aspects and key elements in a successful adaptation plan for climate change?

The interview questions were semi-structured and open-ended. An interview framework had been designed with a general question list being provided to interviewees before the conduction of each interview. Corresponding to the above five issues, the questions were broken into four categories: Part A, identifying the vulnerabilities of ports posed by climate change; Part B, assessing risk and planning priorities; Part C, recognizing the characteristics and differences of ports' condition; Part D, Constructing the environment and stakeholders for an adaptation plan; Part E, implementing an adaptation plan and developing adaptation strategies. However, there was no fixed wording for interviewers to ask questions, and the respondents were not restricted to answering the questions according to the categories. The process was expected to reflect the real situation of specific climate change impacts on targeted ports, as well as the real thinking of interviewees' perception on the port planning process for climate change, adaptation strategies and planning for climate change, and climate-related policies, etc.

Overall, all the interviewees were asked the same basic questions in the same order. At the same time, based on the previous research about the port's history and planning background for climate change (e.g., has the port suffered from the climate change in the past decades? Has the port implemented an adaptation plan already?), the specific wording and sequence of the questions varied among different interviewees. This strategy allowed us to increase the possibility that all the prepared questions in the checklist would be adequately addressed within the limited time frame of the interview (the duration of each interview was around one to two hours).

In particular, for the case of CentrePort Canada and Hudson Bay Railway, in line with the guideline on case study analysis by Miles and Huberman (1984), a within-case analysis and cross-case analysis were utilized to address the above interviews' questions and to fulfill the design purposes. First, for each case, a within-case analysis is very important to investigate the existing climate change risks and potential uncertainties, as well as the implementation of adaptation strategies and planning for climate change on a typical inland port in Canada. Furthermore, a cross-case analysis provided for comparing and contrasting the specific situational context of climate change impacts, adaptation planning for climate change and other associated issues of CentrePort and Hudson Bay Railway under the background of a port supply chain. Also, a within-case analysis and a cross-case analysis strengthened the external and internal validity (Yin, 2003). Meanwhile, to guarantee the construct validity, a diverse data source of evidence, including interview data and archival data in every case study, was identified and analyzed for triangulation. The reliability and traceability was ensured by a series of consistent procedures of case study from the case design and data collection to the analysis, as well as a standardized form of interview from preparation, personal conversation, audio-recording to final transcription (McCutcheon and Meredith, 1993).

Finally, all the data in the interviews were coded by a thematic coding analysis approach. As a generic and flexible method in analyzing qualitative data, thematic coding analysis provided an effective approach to categorize and summarize the key characteristics of numerous qualitative data, thereby achieving the interview purpose (Braun and Clarke, 2006). The data were dealt with following the five phases in a thematic coding analysis (Robson, 2011). *First, familiarizing the data.* Once the interview transcripts form, the context was analyzed line-by-line so as to break the data down into discrete parts. *Second, generating initial codes.* The transcribed data were extracted in a systematic technique across the entire data set and then to be coded (e.g., words, sentences and paragraphs). *Third, identifying themes.* Once the coding procedure was completed, the coded data were categorized into different themes. *Fourth, constructing thematic networks and making comparison.* After connecting the different themes and organizing sub-themes, a thematic network was mapped. *Finally, integration and interpretation.* After comparing the different dimensions of the data in the thematic network, the result of data analysis was generated through exploring, describing, summarizing and interpreting the patterns in the previous phases.

Chapter Four: A Study of Canadian Ports in Adapting to the Risks and Uncertainties Posed by Climate Change

4.1 Introduction

Climate change is at the forefront of research due to its potential catastrophic risks to human welfare. However, with the critical role that ports play in global supply chains (Ng and Liu, 2014), still, it is restricted to developing adaption plans against climate change impacts among a few ports in Canada. To address this problem, it requires a concerted effort by researchers to develop effective analytical tools and generate reliable data so as to help policymakers and other port stakeholders to develop effective adaptation strategies. Understanding such, this chapter investigates the strategies of Canadian ports (including both seaports and dry ports) in adapting to the impacts (associated with both risks and uncertainties) posed by climate change.

Through a nation-wide survey, it aims to figure out the perception of port planners and stakeholders on climate change impacts, current measures and future planning on their ports, in order to illustrate the general situation of this topic among Canadian ports and further justify the necessity of adaptation strategies and planning. Thanks to the assistance of Association of Canada Port Authorities (ACPA) and Green Marine, this survey targets the managerial levels of Canadian ports in geographic areas with varying impacts posed by climate change, which was assumed on behalf of the typical risks and uncertainties and reality of adaptation planning among Canadian ports. A sample of 26 respondents from 21 Canadian ports (e.g., Port of Montreal, CentrePort Canada, Port of Churchill, Port of Sydney (NS), Windsor Port Authority, etc.) were selected to assess the perception of port planners and stakeholders on climate change risks, including perception for general climate change risks and specific impacts on their port operation, performance, facilities, and infrastructure. The survey also involved questions concerning current and long-term port planning by considering climate change risks and uncertainties and how strategic adaptation planning would impact the efficiency of port supply chains. It collects primary data to fill the gaps in the field of dry ports, adaptation strategies and planning, as well as regional studies of ports in Canada so as to provide an innovative reference for global studies.

The rest of the chapter is structured as follows. Sections 2 consist of the hypotheses, while section 3 consists of the analytical results. Finally, the discussions and conclusion can be found in section 4.

4.2 Hypotheses Testing

4.2.1 Hypotheses and data analysis

To investigate the general situation of climate change and adaptation planning at Canadian ports (Objective 2), the following three hypotheses were proposed in order to address two primary aforementioned issues (1.How effectively do adaptation measures address climate change impacts? 2.What are the differences or similarities of climate change impacts on Canadian seaports and dry ports?).

Hypothesis 1: Adaptation strategies minimize the existing impacts of climate change on ports: there are fewer impacts of climate change on a port if an adaptation measure has been implemented than the impacts on a port if adaptation measures have not been implemented in the past decade.

Hypothesis 2: Adaptation measures and the existing impacts of the climate change on ports are positively relevant: there are more adaptation measures are implemented if there have been more risks and uncertainties on ports posed by climate change in the past decade.

Hypothesis 3: There are different impacts of climate change on seaports and dry ports: there are fewer impacts of climate change on a dry port than on a seaport in the past decade.

SPSS software was used to run the collected data. *T*-test, regression and correlation analysis were undertaken to investigate the effects of adaptation strategies for minimizing the climate change impacts on ports and the relations between adaptations and risks and uncertainties (hypothesis 1-2). *T*-test analysis was also utilized to examine the statistical significance of risks and uncertainties posed by climate change on seaports and dry ports (hypothesis 3). The hypothesis testing can be found below.

4.2.2 Hypothesis testing

T-test was used to handle the data in the Hypothesis 1. Here, the dependent variables were the impacts of climate change: 1) SLR and storm, measured by frequency and severity of consequences in the Q4 and Q5 (Sea level rise impacts/Increased intensity and/or frequency of high winds and/or storms in the past 5 years (*frequency (1to 5): very frequent (1) to never (5); severity of consequences (1 to 5): catastrophic (1) to negligible (5));* 2) the risks and uncertainties, measured by the number of climate change events in the Q6 and Q7 *(What types of risks and uncertainties do you think posed by climate change at your port/terminal in the past 10 years?): 1 to 9: 1 to 9 types of risks/and uncertainties.* The independent variable was dichotomy, whose data could be recognized in Q14 *(What protective measures do your port currently have in coping with climate change?)*: *0 represents that no adaptation measures have been implemented in the past decade, and 1 represents that adaptation* *measures have been implemented in the past decade*. First, all the data were coded by categories. For example, in Q4, the 5 items (a) to (e) under the Frequency were coded as *SLR frequency a, SLR frequency b, SLR frequency c, SLR frequency d and SLR frequency e* respectively. The results indicated that there was no significant difference between the data with and of without measures, and all the mean value except storms frequency c without measures (M=3.38) and SLR severity e with measures (M=5.10) was equal to or greater than 4.00 and smaller than 5.00, which means the impacts of SLR and storms were seldom and minor in terms of frequency and severity of consequences. Only in *SLR severity e (Deposition and sedimentation occurred along your port/terminal were flooded or damaged because of sea level rise*), the SLR severity without adaptation measures was minor (M=4.33>4), but with adaptation measures is somewhat negligible (M=5.10>5); in *storms frequency c (Your port/terminal operation was shut down due to higher winds and/or storms),* the storms frequency without measures is sometimes (M=3.38>3), but with measures was seldom (M=4.12>4). Table 2 showed that each p value was greater than 0.05, namely, there was no significant difference of SLR and storms impacts with and without measures.

Afterwards, averaging the data in each category, four types of data were obtained: 1) the mean of frequency and severity of SLR impacts; 2) the mean of frequency and severity of high winds and storms impacts; 3) the sig (2-tailed) value of averaged SLR impacts; 4) the sig (2-tailed) value of averaged high winds and storms impacts. All the mean value expect (M sto_ave_fre- without measures =3.9375) were greater than 4.00, which means the average impacts of SLR and storms were seldom and minor in terms of frequency and severity of consequences. Meanwhile, there was no significant difference between the data of with and of without measures. Only in *storms average frequency*, the storms frequency without measures is sometimes (M=3.9375>3), but with measures was seldom (M=4.4722>4). In Table 4, each p value was greater than 0.05, which represents that there was no significant difference of SLR and storms impacts with and without measures averagely. Thus, it can be concluded that there was no significant difference of climate change impacts on ports in terms of SLR and storms with and without measures by testing no matter every item or mean values under the categories of frequency and severity of consequences. In other words, the adaptation measures have not obvious effects in minimizing SLR and storms; the impacts of SLR and storms were seldom and minor in terms of frequency and severity of consequences.

In addition to the primary impacts from SLR and storms, the general risks and uncertainties of climate change on ports were analyzed. As Table 5 and Table 6 illustrated, the mean values of each item were: M risks- without measures =1.25, M risks- with measures = 2.94, M uncertainties- without measures =2.00, M uncertainties- without measures =3.44. The sig (2-tailed) values are: F risks (1, 26)= 1.349, P risks =0.010 < 0.05, F uncertainties (1, 26) =0.225, P uncertainties =0.052 > 0.05). Accordingly, it can be summarized that there was significant difference of risks with and without measures, but there was no significant difference of uncertainties with and without measures. Meanwhile, the bootstrap result shows that there is a significant difference of risks with and without measures (0.005), but there is no significant difference of uncertainties with and without measures. In other word, the ports that have taken adaptation measure in the past decade have fewer risks but unnecessarily have fewer uncertainties. Therefore, these results partially supported H1.

Regression analysis was utilized in Hypothesis 2 (H2) to examine the relationship between the number of measures have been taken and risks occurred, as well as the uncertainties occurred in the past decade respectively. First, the 10 items in Q6 as 6a, 6b,…, 6j and the 10 items in Q7 as 7a, 7b,…,7j are coded in order. Thus, the number in each questions represented the number of measures that has been taken in the past decade. Similarly, for H2, the dependent variable was the number of adaptations measures implemented in the past decade measured by the number of items choose in Q14: *1 to 12: 1 to 12 adaptation measures*. While the independent variables were the numbers of risks and uncertainties on ports posed by climate change in the past decade measured by the number of climate change events in the Q6 and Q7 respectively. From the analytical results, the author can canclude that the number of measures that have been taken was positively related to the number of risks and negatively related the number of uncertainties and in the past decade. However, the bootstrap data showed that P risks-with measure =0.000<0.05, R^ risks-with measure =0.526, B risks-with measure =0.832, and P uncertainties-with measure =0.004<0.05, R^ uncertainties-with measure =0.293, B uncertainties-with measure =0.564. To summarize, the number of adaptation measures implemented was positively relevant to the number of risks but not significantly relevant to the number of uncertainties pose by climate change in the past decade. Thus, H2 can be partially confirmed.

Moreover, ports were divided to seaports and dry ports to further figure out the implementation of protective measures. In Table 8, R^ with measure-sea =0.613, P risks-with measure-sea =0.003<0.05, B risks-with measure-sea =1.534, P uncertainties-with measure-sea =0.097>0.05, and B uncertainties-with measure-sea =-0.708, namely, the number of adaptation measures have been implemented was positively related to the number of risks occurred but not significantly related to the number of uncertainties occurred on the seaports in the past decade. In Table 9, R^ with measure-dry =0.900, P risks-with measure-dry =0.006<0.05, B risks-with measure-dry =2.467, and P uncertainties-with measure-dry =0.042<0.05, B uncertainties-with measure-sea =-1.367. Namely, the number of measures have taken was positively related to the number of risks and negatively related the number of uncertainties on the dry ports in the past decade. Bootstrap results showed a little different results that on seaports, the number of measures have taken was positively related to the number of risks as well as the number of uncertainties on the dry ports in the past decade, while on dry ports, the number of adaptation measures that have been implemented was positively related to the number of risks occurred but not significantly related to the number of uncertainties occurred in the past decade.

Combining the results of regression analysis and bootstrap for seaports and dry ports, it can be concluded that there is a positive relationship between the number of measures and the number of risks for both seaports and dry ports; however, the relationship between the number of measures and the number of uncertainties was not significant. In summary, there were more adaptation measure that have been implemented if there were more risks occurred in the past decade no matter on seaports or dry ports. It means that port administrators are more focused on the risks rather than uncertainties posed by climate change with the more implementation of adaptation measures. Thus, again, H2 was partially confirmed.

T-test was conducted to investigate the difference of impacts of climate change on seaports and dry ports in H3. In this design, the independent variable was the type of ports (seaports or dry ports), which will be recognized in Q3 (*What's the name of your port?*): 0

represents seaports, and 1 represents dry ports. Meanwhile, two pairs of dependent variables involved: 1) SLR and storms, measured by frequency and severity of consequences in the Q4 and Q5*; 2)* the risks and uncertainties, measured by the number of climate change events in the Q6 and Q7.

First, the different impacts of SLR and storms on seaports and dry ports were analyzed. By utilizing t-test, the mean values and the sig (2-tailed) value of every item were obtained (See Table 10 and Table 11). For each item in SLR and storms, in overall, the frequency of SLR and storms were seldom, and the severity of consequences was minor (3<M<5). However, there were several differences in terms of the mean value. In *SLR frequency d (Deposition and sedimentation occurred along your port/terminal's channels),* as well as in *storms frequency c (Your port/terminal operation was shout down due to higher winds and/or storms)*, the frequency in seaports was sometime (M=3.88>3; M=3.72>3) while in dry ports is seldom (M=4.43>4; M=4.29>4). In *storms severity d (Overland access to your port/terminal was limited due to higher winds and/or storms)*, the storms severity in seaports was sometimes (M=3.86>3) while in dry ports was negligible (M=5.20>5). In SLR *severity (a, b, c, d and e) and storms severity (a and b)*, the severity on the seaports (M=4.60, 4.90, 4.33, 4.46, 4.64>4; M=4.36, 4.33>4) was minor while in dry ports was negligible (M=5.40, 5.33, 5.20, 5.00, 5.20>=5; M=5.00, 5.00>=5). Nevertheless, the results showed that each p value was greater than 0.05, thus indicating that there was no significant difference of every item in SLR and storms impacts on seaports and dry ports. Furthermore, averaged the data in each category were obtained (seen Table 12 and Table 13). As Table 12 illustrated, the average impacts in terms of the frequency in SLR and storms were seldom on both seaports and dry ports (M>4). However, the average impacts in terms of the severity in SLR and storms on seaports and dry ports were different: for *SLR and storms average severity*, the average severity on seaports is minor (M=4.5000>4; M=4.0000), but on dry ports measures is negligible (M=5.2857>5; M=5.0000). According to Table 13, statistically, there was no significant difference between seaports and dry ports in terms of SLR average frequency and storms average severity (p=0.064>0.005; p=0.053>0.005). Whereas, there was significant difference between seaports and dry ports in terms of SLR average severity and storms average frequency (p=0.033<0.05; p=0.014<0.05).

Summarizing the results of mean values and p values in Table 10, 11, 12 and 13, there was significant difference between seaports and dry ports in terms of SLR average severity: the SLR average severity on seaports was stronger than that on dry ports, which is consistent with the conclusi*on in Table 10 (In SLR severity (a, b, c, d and e) (M=4.60, 4.90, 4.33,* 4.46, 4.64>4;) is minor while that in dry ports is negligible (M=5.40, 5.33, 5.20, 5.00, 5.20>=5)). At the same time, the bootstrap results were consistent with these conclusions: there was no significant difference on seaports and dry ports by examining the every item in SLR; similarly, there was no significant difference of climate change impacts on seaports and dry ports in terms of every item in storms excepted *in storm frequency c (Your port/terminal operation was shut down due to higher winds and/or storms)*. However, the bootstrap result of average impacts of SLR and storm demonstrated that there were significant differences on seaports and dry ports (Pslr_ave_sev=0.050, P sto_ave_fre =0.003, P sto_ave_sev =0.013 <= 0.05). Besides SLR and storms, the differences of general risks and uncertainties were examined on seaports and dry ports. Table 14 and Table 15 illustrated that the mean values are between 2 and 4 (M risks-sea =2.32, M risks-dry =2.71, M uncertainties-sea =2.89, M uncertainties-dry=3.29), and p values are greater than 0.05 (F risks (1, 26) = 3.345, P risks =0.585>0.05, F uncertainties (1, 26) =4.124, P uncertainties =0.627> 0.05). Therefore, it can be concluded that there was neither significant difference between types and risks nor between types and uncertainties. Meanwhile, the bootstrap result confirmed the non-significance between types and risks and uncertainties. In other word, the impacts of climate change posed little difference on seaport and dry port with respect to risks and uncertainties. Thus, H3 was partially confirmed.

4.2.3 Hypothesis retesting

In retrospect to the results of the previous three hypotheses, it is noticeable that the moderate effects of protective measures are different in terms of the number had been taken (without/with; more/fewer) in the past decade and the type of ports (seaports and dry ports). Meanwhile, as the impacts of climate change are measured by SLR and storms (every items and average values of frequency and severity), as well as by risks and uncertainties, the results are various so as to partially support H1, H2 and H3. Based on this conclusion, it is worthwhile to consider that if SLR and storms, as traditional primary impacts of climate change, can represent the overall situation of climate change impacts, and if SLR and storms are related to risks and uncertainties. In addition, since there is a variety of difference in characteristics and climate change impacts (H3) between seaports and dry ports (e.g., it is supposed that SLR and storms might be the main impacts of seaports but not be the main impacts of dry ports), the previous hypotheses will be retested on seaport and dry ports.

First, to examine the relationship between SLR, storms and risks and uncertainties, correlation analysis was utilized. Similarly, the impacts of SLR and storms were measured by the average values in frequency and severity of consequences in Q4 and Q5, and the risks and uncertainties were measures by the number of items being chosen in Q6 and Q7. As Table 16 indicated that there was statistical correlation between risks and SLR average severity at the 0.05 level (2-tailed) ($p=0.02<0.05$), while for other three items (SLR average frequency, storms average frequency and severity), there was no significant correlation between of them and risks and uncertainties. The bootstrap result showed that there was no significant correlation between SLR, storm and risks and uncertainties at the 0.05 level (2-tailed) (all $p>0.05$). Accordingly, it can be concluded that there was no obvious correlation between SLR, storms and risks and uncertainties, and thus SLR and storms had no obvious correlation with the risks and uncertainties so as to be the representatives of primary climate change impacts from this perspective. Meanwhile, this conclusion justified the different results in H1 and H3: there were neither significant difference with and without measures in terms of SLR and storms, nor uncertainties, while there was significant difference in risks; there were some significant differences in seaport and dry ports in terms of average frequency and severity of SLR and storms, while there were neither significant difference in terms of every items in SLR and storms nor risks and uncertainties. Understanding such, the previous hypotheses will be further retested by dividing ports into seaport and dry ports respectively.

Following the above analysis, this chapter further investigated if SLR and storms can represent the primary impacts, namely if SLR and storms are related to risks and uncertainties on seaport and dry ports. As Table 17 demonstrated, on seaports, risks and uncertainties had a strong correlation at the 0.01 level (2-tailed) ($P=0.000<0.01$), while for SLR and storms, only storm average frequency was significantly related to risks at the 0.05 level (2-tailed) ($P=0.049<0.05$). The results hinted that on seaports, risks and uncertainties were interdependent or hard to distinguish to some extent, and SLR and storms are partially relevant with risks and uncertainties. Therefore, SLR and storms could not totally represent the climate change impacts on seaports. For dry ports, as table 18 showed, risks and uncertainties had a strong correlation at the 0.05 level (2-tailed) ($P=0.017<0.05$), whereas there is no significant correlation between SLR, storms and risks and uncertainties (all $p>0.05$). Therefore, neither SLR nor storms were related to risks and uncertainties so could not represent the climate change impacts on dry ports. Furthermore, bootstrap results confirmed the conclusion that risks and uncertainties had a significant correlation at the 0.01 level ($p=0.000$) and 0.05 level ($p=0.017$) on seaports and dry ports respectively, while there were no significant correlations between SLR, storms and risks and uncertainties on seaports and dry ports.

Thus, these retests on seaports and dry ports are also consistent with the previous conclusion that SLR and storms were partially related to risks and uncertainties so as to partially represent the primary climate change impacts on seaports but had not obvious relations to risks and uncertainties on dry ports, which further clarifies our judgments to HI and H3.

Following the above discussion, H1 was further retested on seaports and dry ports respectively. This chapter first examines the effects of measures on seaports. As Table 19 illustrated, although all the data were in the range between 3 and 5, there were 10 groups of data in the different range of mean values. Compared with the mean results in H1, there were more varieties with and without measures on seaports than on all the ports. Simultaneously, on Table 20, majority p value was greater than 0.05, which represents that there was no significant statistical different SLR and storms impacts between with and without measures, however, there was significant difference between with and without measures in *storms frequency d (Overland access to your port/terminal was limited due to higher winds and/or storms) on seaports* ($p=0.032<0.05$). Also, focusing on the average values of severity of frequency in SLR and storms, Table 21 implied that all the mean values in SLR were greater than 4.00, which means the average impacts of SLR were seldom and minor in terms of frequency and severity of consequences. However for storms, the storms average frequency without measures was sometimes while with measures was seldom; the data in storms average severity with and without measures both are minor. Table 22 further indicated the differences in storms average frequency that there was significant statistical difference in storms average frequency with and without measures on seaports ($p=0.017<0.05$).

For dry ports, as Table 23 illustrated, nearly all the mean values were greater than 4 and most of data were in the different range of mean values. Compared with the mean values in H1, there were more varieties with and without measures on dry ports than on all the ports. On Table 24, majority p value was greater than 0.05, which represents that there was no significant statistical difference of SLR and storms impacts with and without measures, however, there was significant difference between with and without measures in *SLR frequency d (deposition and sedimentation occurred along your port/terminal's channels) on dry ports* ($p=0.029<0.05$). Also, focusing on the average values of severity of frequency in SLR and storms, Table 25 implied that all the mean values were no significant statistical differences within one category: in SLR average frequency and storms were greater than 4.00, which means the average impacts of SLR were seldom and minor in terms of frequency and severity, while in SLR average severity, the mean value of with and without are greater than 5, which means the severity was negligible. At the same time, Table 26 indicated that averagely, there was no significant statistical difference in SLR and storms between with and without measures on dry ports (all $p>0.05$). It is also noticeable that because there were more mean values greater than 5 (never in frequency) or equal to 6 (missing data) (Table 23 and Table 25), it can be thought that SLR and storms had fewer impacts on dry ports than on seaports.

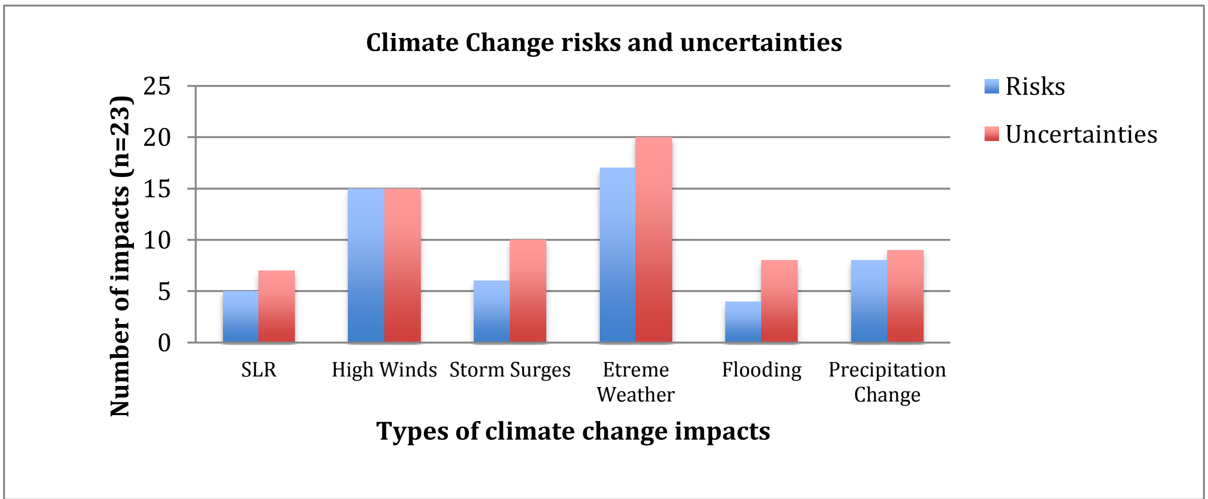
Through retesting H1, the t-test results were different when the ports are divided into seaports and dry ports: compared with the non-significances in SLR and storms between with and without measures on all ports, there were some significant differences on seaports and dry ports. Specifically, for seaports, there was significant difference between with and without measures in storms frequency d (Overland access to your port/terminal was limited due to higher winds and/or storms) on seaports; there was significant statistical difference in storms average frequency with and without measures on seaports. For dry ports, there was significant statistical difference between with and without measures in SLR frequency d (deposition and sedimentation occurred along your port/terminal’s channels) on dry ports. In other word, adaption measures had obvious effects in reliving storms frequency, especially in reducing overland access deposition and sedimentation in seaports, as well as in reducing SLR frequency in deposition and sedimentation dry ports. These different effects of measures in different type of ports might stem from the previous conclusion that SLR and storms have fewer impacts on dry ports than seaports.

4.3 Analytical Results

4.3.1 Climate change perceptions and attitudes in the past decade

To assess the impacts of climate change in the past decades, while examining the SLR and storms in the previous three hypotheses, the impacts are divided into "risks" and "uncertainties" to elicit an overview as to how climate change impacted Canadian ports in the past decade. In overall, respondents acknowledged a higher frequency in risks over uncertainties, except the category "storms" which has equal number of responses. This means that respondents have realized some certain and critical climate change events, however, for uncertain impacts, they may fail to notice or to be less informed. Interestingly, instead of SLR and storms, extreme weather and high winds were the most concerned impacts for both risks and uncertainties, with 77.27% and 86.96% in extreme weather and 68.18% and 65.22% in high winds respectively. Storm surges became the third frequent uncertainty, however, precipitation change was a more noticeable risk rather than storms surge or SLR (see Figure 1).

Figure 1-Cimate change risks and uncertainties in the past decade



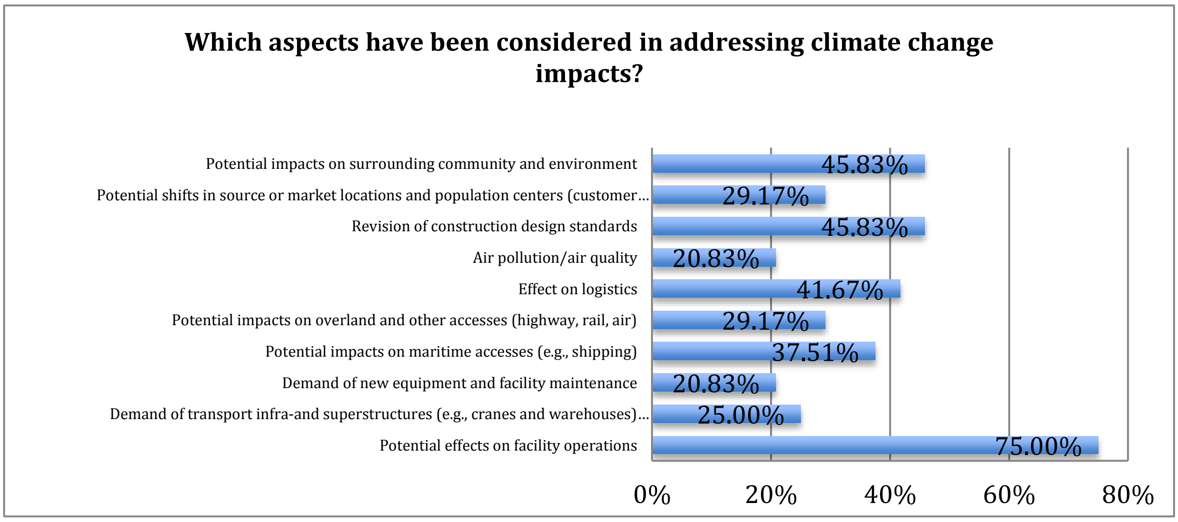
Meanwhile, respondents were asked to write down the top three climate change impacts.

Although qualitative answers vary in different ports and areas, results could be summarized to analyze their common characteristics. Unsurprisingly, extreme weather (unpredictable patterns, hot summer, polar vortex, heavy, and less or freezing rain) was put to the top list with 15 responses, high winds and storm surges, as well as water level change (e.g., rise, decrease, flooding) were the other most concerns with 13 and 5 responses respectively. To further investigate the differences in seaports and dry ports, the data were recollected and it is found that extreme weather, high winds and storm surges, and SLR were still the top three issues. Nevertheless, high winds and storm surges most frequently happened on seaports, while extreme weather was the most frequent incidents on dry ports.

4.3.2 Current adaptation planning for climate change

Before asking the details about adaptation plans for climate change, respondents were required to answer if their ports have implemented or will implement an adaptation plan for climate change. Only 2 respondents (7.69%) reported that their ports currently have an adaptation plan, while majority (73.08%) indicated that their ports have not implemented an adaptation plan but will consider it in the future. Also, 5 respondents (19.23%) thought that an adaptation plan was neither implemented nor will be implemented in the future. The result was consistent with the previous research of a global survey conducted by Becker in 2012, revealing that although most of port administrators in Canada have realized the significance of an adaptation plan for climate change, only a very limited number of them have adaption planning. Referring to the comments and further explanations from some respondents, several ports have conducted protective or adaptive measures, but which has not been identified as an adaptation plan. Nevertheless, respondents' positive consideration for adaptation planning laid a favorable foundation for assessing their perceptions about planning and measures for climate change impacts in the following sections. To further acquire information of how respondents considered in handling with climate change impacts, a list obtaining 10 possible issues were generated for their reference. As Figure 2 illustrated, the major concern of respondents (75%) fell on potential impacts on facility operations posed by climate change, followed by potential impacts on surrounding community (45.83%) and environment as well as revision of construction design standards (45.83%). Also, over half of respondents were concerned over surrounding environment (45.83%) and air pollution/ air quality (20.83%), and both two items can be categorized into "mitigation" strategy. Whereas, aspects related to "adaptation", such as demand of new equipment and shifts in source or market location have not been given enough attention.

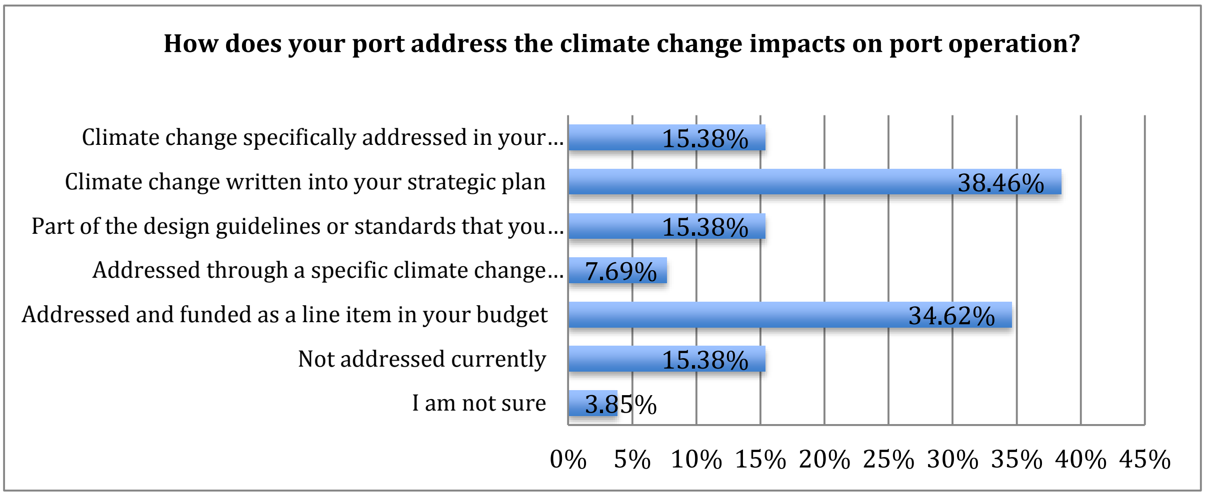
Figure 2-Climate change considerations



The above analysis suggested that most considerations were remained on operational level for addressing climate change impacts, the other two questions were proposed to analyze how do the ports address climate change and what specific protective measures have been taken in coping with climate change impacts from the perspective of port operation.

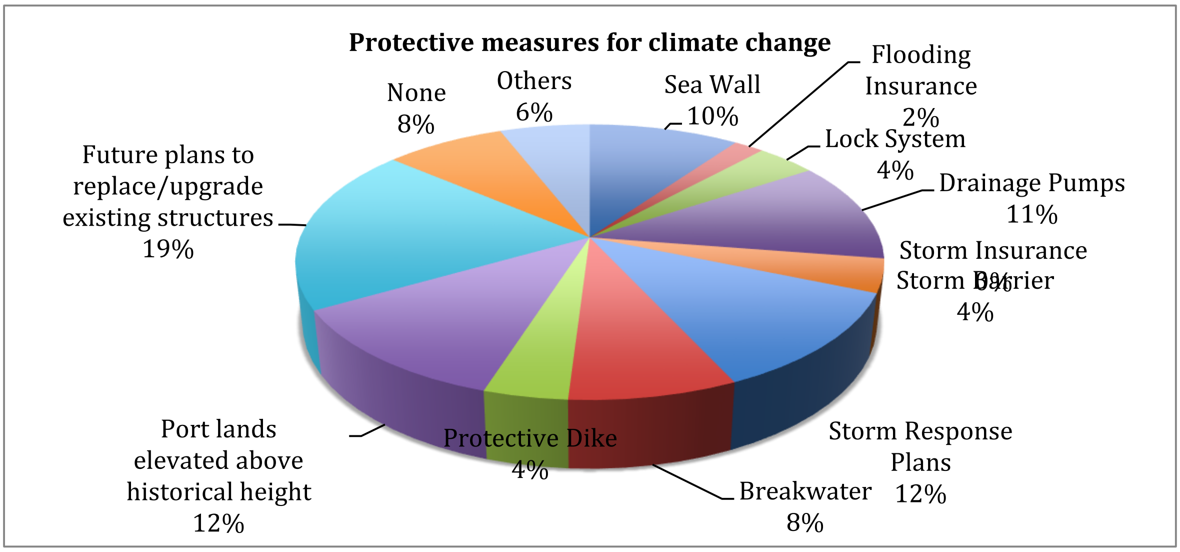
Although only a minority of ports in this survey has an adaptation plan for climate change impacts, still, most ports have considered coping with climate change issues on port operation as Figure 3 and Figure 4 illustrated. When respondents were asked how their ports address climate change impact on operation, over 70% have put climate change into their strategic plan and addressed and funded as a line item in port's budget (see Figure 3). This means that, in most cases, climate change issues have been already noticed and integrated to a port's strategic level; considerable funding has been given to minimize impacts on operation. Simultaneously, only less than 8% of the respondents thought that climate change impacts were addressed by a specific climate change-planning document, and this result could partially explain the short of adaptation plans for climate change in above analysis.

Figure 3-Measures for addressing climate change impacts on port operation



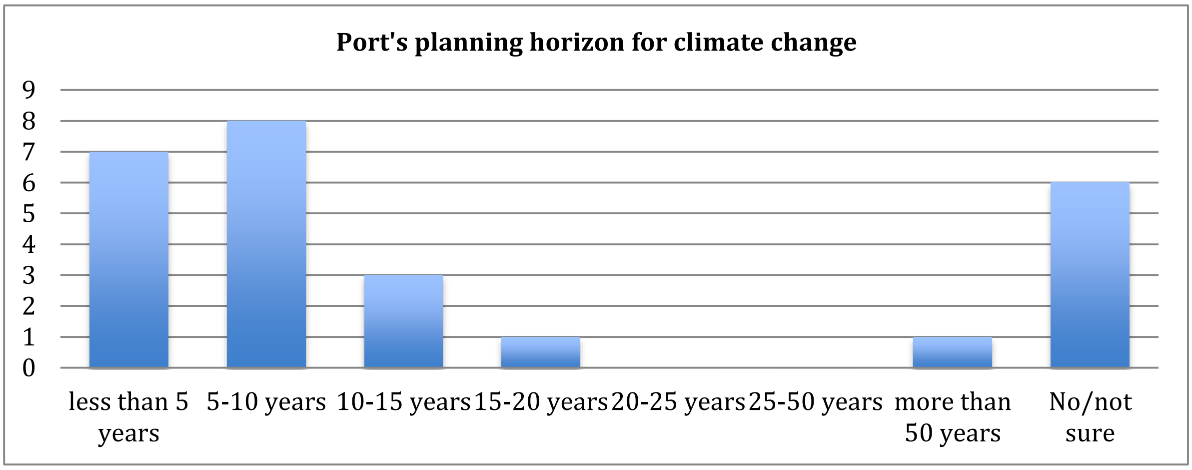
Afterwards, respondents were asked to provide more details about protective measures in coping with climate change issues. Since major respondents from seaports, they were more likely considering ocean-related protective plans. As represented in Figure 4, storms response plans, drainage pumps, port lands elevation and sea wall each occupied over 10% of all the measures. For dry ports, administrators considered flooding, dredging plans, riprap, and business interruption insurance etc. in terms of the different reality of different ports. However, a few respondents pointed out that they did not know or were not confident if protective measures have had been implemented by their port entity or authority, and it is common that around one fifth respondents were looking forward to future plans to replace/upgrade existing structure.

Figure 4-Protective measures for climate change



Finally, this chapter looked at the planning timeline of climate change (Figure 5), although port's planning horizon might be project-based and various subject to its outcomes (Becker, 2012), most respondents considered a 5-10-year or less-than-5-year plan in their mind. As one respondent explained, the 5-year planning was consistent with 5-year business plan cycle. The few minor exceptions were from 10-15 years, 15-20 years, and only one respondent indicated they were making a 50-year plan for climate change according to the cycle time of typical wharf facilities. Since there were only a limited number of ports having a current specific plan for climate change, some respondents felt difficult to give a confirm answer or reference.

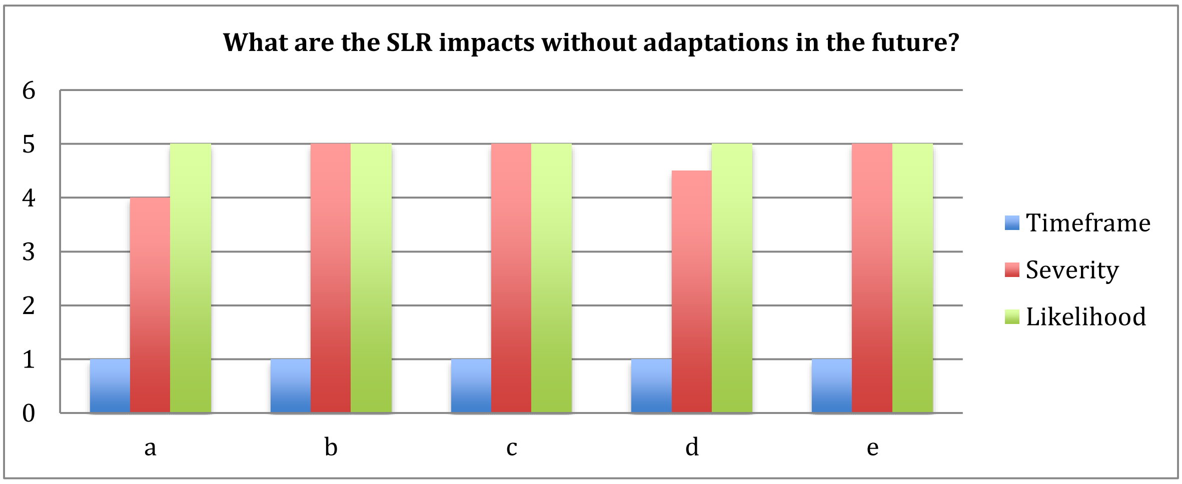
Figure 5-Port's planning horizon in years



4.3.3 Climate change impacts in the future

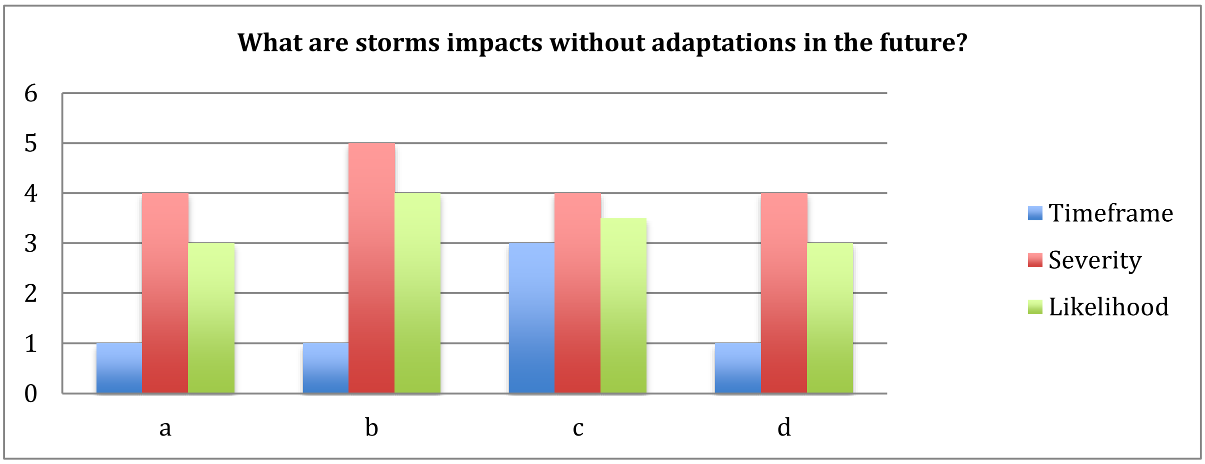
Based on the former analysis, even though SLR and high wind or storms were not the most striking types of impacts, they were still posing potential risks or uncertainties on ports, especially when the respondents were mainly from seaports where high wind or storms was their top concerned impacts. Understanding such background, four questions were designed to allow respondents to stimulate the impacts of SLR and storms in the future, which included the estimate of "Timeframe in which you will expect to first see this impacts", "Severity of consequences", "Likelihood that the event will occur" if no adaptation measure will be undertaken, and added "Financial cost of adaptation measure" if adaptation will be undertaken in the future. Similar to analyzing the data in hypotheses, all the data were coded from 1-5 in each category. Through collecting the most frequent data in every item, Figures 6, 7, 8, and 9 were drawn to compare and contrast the impacts of SLR and storms with or without adaptations in the future. Respondents were firstly required to estimate SLR impacts if adaptations will not be undertaken in the future (Figure 6). Since SLR was not the top concern neither for seaports nor dry ports, unsurprisingly, most respondents thought there was going to be a very long (over 20 years) and very low likelihood to suffer from SLR impacts even without adaptation measures for each five aspects of SLR. Meanwhile, for severity of consequents, majority felt negligible impacts on transportation, access and costal erosion posed by SLR with the implementation of adaptation measures (b, c, and e in Figure 6). However, most respondents expected a minor impact on higher waves that will damage port's facilities and ships berthed alongside, as well as more than negligible impacts on deposition and sedimentation that will occur along port's channels, which means that the impacts from higher waves, deposition and sedimentation were more serious than others.

Figure 6-SLR impacts without adaptations in the future



Ps: (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.

Figure 7-Increased high winds and/or storms impacts without adaptations in the future



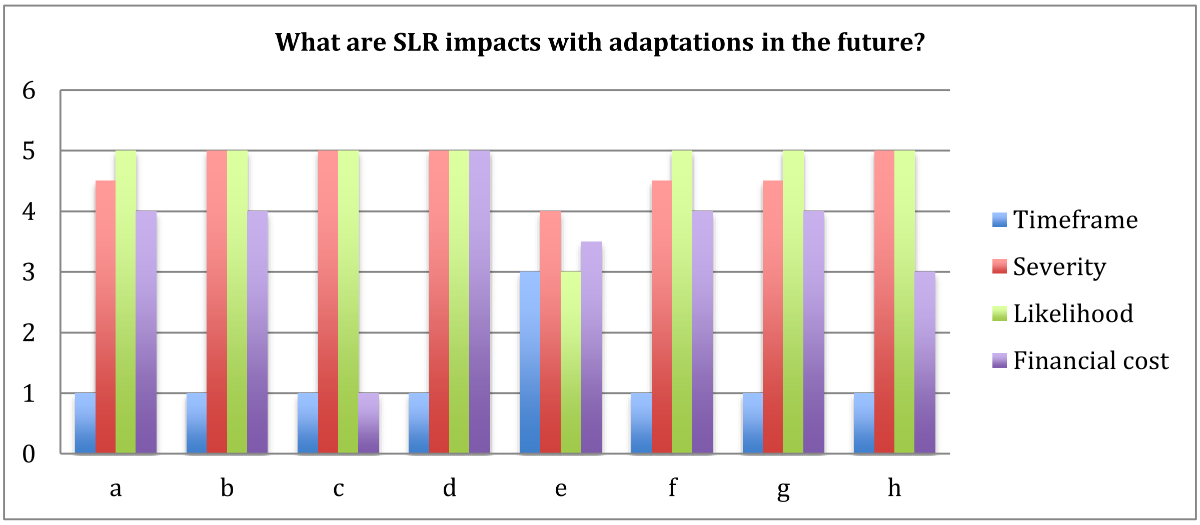
Ps: (a) Higher waves that will damage port/terminal's facilities, and ships berthed alongside (b) Transport infra- - and superstructures and utilities in the port/terminal will get flooded or damaged in more intense or frequent storms (c) Downtime in port/terminal operation due to the increase of high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

High winds and storms, as the top impacts on seaports, were estimated to have more impacts than SLR as showed in Figure 7. In terms of the timeframe of seeing the first event happening, downtime in port operation was regarded as medium impacts (c) while rest aspects were still negligible impacts. Excepting flood in transport infra- and superstructure with negligible severity and low likelihood, major three aspects (a, c, and d) were expected low severity and average likelihood in the future. As Figure 7 showed, downtime in port operation due to the increase of high winds and storms(c) was thought to be the most striking impact with a shortest timeframe and relatively higher likelihood. Combing the results in SLR and storms, it can be concluded that generally speaking, without adaptations, high winds and storms were expected to pose greater impacts on ports. This conclusion is similar to the perceptions about current impacts of SLR, high winds and storm on ports as investigated in the previous sections.

ADAPTING TO THE RISKS

When adaptations will be implemented in the future, some changes happened in terms of the above three perspectives, and this issue also involves in the costs of adaptation planning. Figure 8 and Figure 9 demonstrated the perceptions of respondents on SLR and storms impact with adaptations with respect to timeframe, severity, likelihood and financial cost. In expecting the timeframe for first seeing the SLR impacts, 7 out of 8 aspects were recognized to be negligible with an exception in deposition and sedimentation (e), when increases or expand dredging on ports, the impacts were expected to see in approximately 10 years (medium) along port's channels. Since there were most negligible severities from SLR even without adaptations, there was little difference on ports with adaptations in the future with negligible SLR impacts (Figure 8). When it is involved in likelihood, the SLR impacts were minimized to very low with adaptations competed with the average and low without adaptations. Finally, from the financial perspective, most adaptation measures were estimated to very low costs with an exception in deposition and sedimentation as well as all the mentioned risks with average financial costs. Accordingly, it could be seen that adaptations have positive effects in minimizing SLR impacts, especially in SLR severity, with a relatively low costs. Compared with Figure 6, it is obvious that building new breakwater and/or increasing their dimensions can reduce the severity of SLR in damaging on port's facilities and ships berthed alongside due to higher waves with low costs (a in Figure 8). Meanwhile, deposition and sedimentation might be the greatest impacts from SLR when adaptations will be implemented, with a shorter timeframe, stronger severity and higher likelihood than other aspects (see in Figure 8). By increasing and/or expanding dredging, it might reduce the severity of SLR but requires relatively higher financial support.

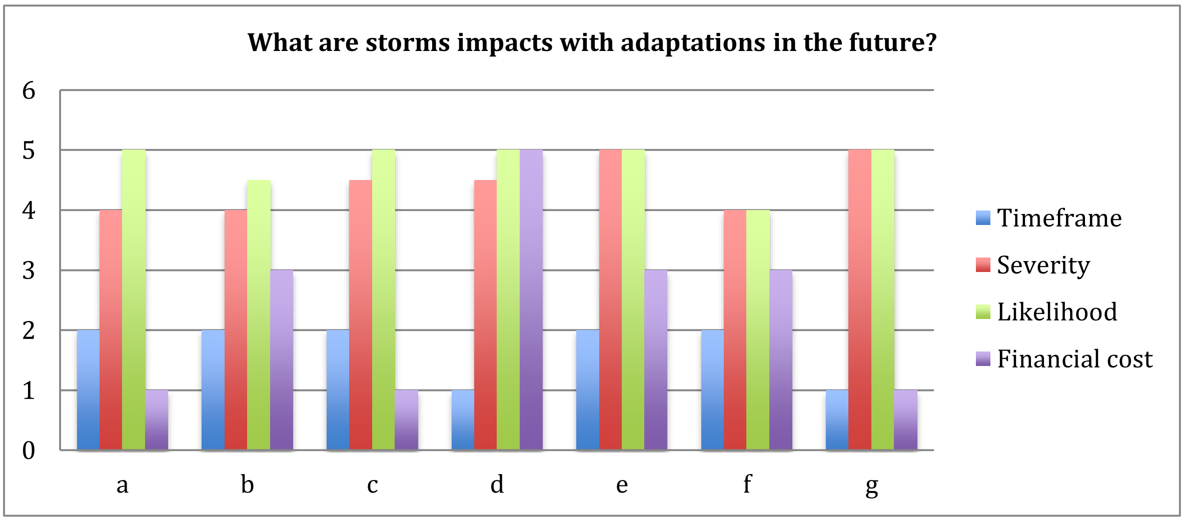
Figure 8-SLR impacts with adaptations in the future



Ps: (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).

Likewise, adaptation measures would make a difference on the impacts of increased high winds and storms in the future (Figure 9). First, through improving management in preventing effects, the severity and likelihood in downtime in port operation were minimized to negligible and very low respectively, although it needs an average budget (e in Figure 9). Also, the establishment of new breakwaters and/or increase of their dimensions would decrease the likelihood of higher waves in damaging port's facilities and ships from average to negligible (a). To cope with the limitation of overland access (road, railway) due to more intense/frequent storms, there were two adaptation measures (c and d in Figure 9), and both of them could relive the likelihood to be negligible. However, rather than improving quality of land connections, diversifying land connections to port/terminal could achieve very low costs (d), and which can be regarded the most economical measure. Overall, adaptations were expected to have considerable effects on minimizing the likelihood of storms' happening, but have neither obvious effects on extending timeframe nor on reducing severity. Moreover, when the financial factors are considered, adapting impacts on high winds and storms demand higher costs than those in SLR. While higher winds and storms have attracted more attention, they call for planners to design more effective adaptation measures and increasing adaption budget limits in handling with impacts of high winds and storms.

Figure 9-Increased high winds and/or storms impacts with adaptations in the future



Ps: (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) 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) 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) (e) Overland access (road, railway) to port/terminal will be limited due to more intense/frequent storms (Adaptation Measure: Diversify land connections to port/terminal) (f) Downtime in port/terminal operation due to the increase of high winds and storms (Adaptation Measure: Improve management to prevent effects) (g) All the risks and impacts above (Adaptation Measure: Move facilities away from existing locations which are vulnerable to climate change risks and impacts).

4.4 Discussions and Conclusion

Although exiting adaptation plans for climate change were identified to be at an early stage, most respondents have considered climate change impacts as part of strategic port planning. Most importantly, a majority of them has showed a positive intention to make a specific adaptation plan for climate change impacts in the future. Therefore, this section is devised to provide port planners with a general direction for further adapting climate change according to the survey results. In comparison with the current port's planning horizon for addressing climate change issues, an adaptation plan usually requires a longer time horizon. Half of the respondents pointed out a 5-10-year horizon, while the rest choices are various in "less than 5 years", "15-20 years" and "20-25 years". Similar to the existing result, several respondents felt they were not informed in making an adaptation plan so that there is no coherent reference to support the decision-making. As one respondent indicated, this time horizon can be determined by the cycle time of typical wharf facility, and which is also regarded an efficient judgment in academia. However, the project-based characteristic in port planning may diversify the time horizon in different ports relying on comprehensive elements (e.g., the timeframe, severity, likelihood of climate change and financial costs of adaptations). When discussing about developing an adaptation plan for climate change, several port's plans will be related, providing references in decision-making. With the short of mature adaptation plans, respondents expressed strong interest in learning advanced experiences from other ports' adaptation planning. Meanwhile, Port Master Plan will be an overall guidance of adaptation planning. Additionally, regional transportation and environmental plan, port's land-use plan, port infrastructure plan, Canada building code, Canada fire code, NFPA Codes, API Codes, OCIMF, ISGOTT and all the hazardous and maritime resilience plans could provide references depending on port's reality.

With the widespread of climate change impacts and penetration of concept of port supply chains in port management, an adaptation plan is not a simple decision made by a port planner with a port entity but calls for external wisdom from diversified stakeholders. Consultants were perceived as the most important participant, whom was followed by labor unions, shipping lines, dock workers, freight, forwarders, NGOs, investment groups. According to the respondents' feedbacks, terminal operators, port users, local vessel agents and the municipal governments, as well as specific associations (e.g., Canadian Shipping Association and Federation, Environment Canada) could also play significant roles in adaptation planning. Moreover, in making an adaptation plan in the future, risk analysis should put in top priority, followed by prioritization and development of strategies for rational implementation. Accordingly, a systematic evaluation method with scientific information in climate change forecast and adaptation would lay a favorable foundation for making a rational planning. Last but not least, to ensure a successful adaptation plan, respondents believed that the priority would be to remove budgetary constraints in order to strike a balance between the benefits of all the stakeholders. Also, public participation and policy will create more opportunities and possibilities of a successful adaption plan.

The chapter offers a board overview on how ports adapt to climate change impacts in Canada through a nation-wide survey among 26 Canadian port administers. Generally, the results demonstrate that extreme weather (e.g., unpredictable patterns, hot summer, polar vortex, and heavy, less and freezing rain), high winds and storms, as well as SLR are the top three impacts on Canadian ports. Specifically, the three hypotheses assist in the quantitative examination of the efficiency of adaptation measures in coping with SLR, storms and risks and uncertainties posed by climate change in the past decade, as well as the differences between seaports and dry ports with regards to these issues. Adaptations were estimated to have positive effects in minimizing SLR impacts, especially in SLR severity of consequences with relatively low costs, while the effects on storms were restricted in reducing likelihood of occurrence. Thus, further adaptation plans call for planners to designing more effective adaptation measures and increasing adaption budget limits in handling with climate change issues. In addition, a systematic evaluation method with scientific information in climate change forecast and adaptation could deal with risk-analysis predicament. Finally, cross-department involvement, public participation and external cooperation including consultants, labor unions, shipping lines, dock workers, freights, forwarders, NGOs, terminal operators, port users, local vessel agents and the municipal governments will contribute to prioritize and develop strategies in planning, policy making and implementation.

Chapter Five: Climate Change and the Adaptation Planning of Inland Port and Rail Infrastructures in the Province of Manitoba in Canada

5.1 Introduction

The Province of Manitoba of Canada (hereinafter called 'Manitoba'), due to its central location in North America and natural resources, is a well-known agricultural province in Canada. One of the most important pillar industries is transportation, whose multiple modes (road, air, rail and ship) not only supports the national economy but also catalyzes US-Canada as well as global trade. Meanwhile, since ports (including inland ports) are always regarded as a crucial node and the railway as a vital link connecting ports and supply chains (e.g., the Hudson Bay Railway in Canada), the impacts of climate change in the transportation system could significantly affect the efficiency of regional supply chains.

As Manitoba is located in a relatively interior area and northerly latitude, the impacts of climate change in Manitoba are disproportionate and diverse. Some impacts of climate change on Manitoba's transportation system have been identified. Generally, with the tendency of global warming, Manitoba is expected to suffer from warmer and wetter winters, together with longer, drier and hotter summers: as the most dramatic climate change in the past 100,000 years, the temperature could rise by 3-4 ºC in summer and 5-8 ºC in winter by 2080 (Kyoto and Beyond, 2001), meanwhile, the precipitation could rise by 5-10% and decrease by 10-20% in spring and summer, respectively (Environment Canada, 2014). However, this prediction is uncertain because there have been more dramatic and frequent climate change events (e.g., flooding and melting permafrost) and extreme weather events (e.g., storms, tornadoes and hurricanes), impacting or indirectly affecting, for example, the communities' economy, transportation infrastructure and patterns, as well as the integrity of transportation and supply chain infrastructures, such as CentrePort Canada (hereinafter called 'CentrePort') and the Hudson Bay Railway.

Although a considerable amount of assistance has been given to CentrePort and the Hudson Bay Railway (e.g., the political action plan and funding from federal and provincial government, the infrastructure investments of Highway 75, CentrePort Canada Way, Canadian National Railway (CN), Manitoba Infrastructure and Transportation (MIT), Bison Transport etc., and the relevant academic research and workshops together with forecasting and risk-analysis tools for climate change), they are lack any specific adaptation plans for climate change at both the corporate (CentrePort and Port of Churchill) and governmental (Manitoba and Winnipeg government) levels. However, given the potential risks as stated above, it is believed that strategic adaption planning is very important, in which it would play a pivotal role in minimizing risks and uncertainties posed by climate change, thus maximizing the benefits of every stakeholder in this supply chain.

This chapter investigates the potential risks posed by climate change, and the adaptation strategies and planning by transportation and supply chain infrastructure provider in Manitoba. This chapter focuses on CentrePort and the Hudson Bay Railway (which connects the Canadian National Railway to the port of Churchill located in the Hudson Bay), and analyze the current plans for climate change in this area. It worth mentioning that the analysis procedure for CentrePort and Hudson Bay Railway can be regarded the process that how adaptations plan is generated. Generally, this process starts from identifying the risks and uncertainties posed by climate change on the two entities, investigating the current problems and adaptation measures, analyzing the necessity and resources for an adaptation plan to offering recommendations for adaptation planning. Thus, it is consistent Proposition 1 (Chapter 2) that there lack of a uniform process of adaption planning for climate change impacts in different ports; an instructive guideline and industrial standard would contribute to improving the efficiency of adaptation planning.

In the first section of the chapter, on the basis of several interviews undertaken with the relevant stakeholders in the supply chain, corporate documents and governmental policies, the authors identify the climate change risks (flooding) and uncertainties (the extreme weather events on supply chain interruption and transportation patterns and infrastructure) on CentrePort by positioning it as a transportation hub for North America. Afterwards, this chapter focuses on adaptation planning and analyze the necessity for, and the resources and barriers involved in, the planning process. This chapter then reiterates the significance of adaptation planning for climate change in this supply chain and attempt to encourage more attention to, and discussion of, detailed issues (such as public participation and insurance) in adaptation planning.

As mentioned earlier, it is believed that adaptation planning for this port supply chain is a necessary and significant part of regional and national development. On the basis of analyzing the existing preparations for climate change at CentrePort, adaptation planning for climate change calls for attention from all of the relevant stakeholders. Similarly, the next section examines climate change on the Hudson Bay Rails a two-edged sword creating threats (e.g., melting permafrost) and opportunities (e.g., longer shipping season) along with new challenges for OmniTRAX, the owner and operator of the Hudson Bay Railway and Port of

Churchill in Northern Manitoba, Canada. This also requires a specific adaptation plan for further supply chain management.

Last but not least, by examining climate change and adaptation of the Northern supply chain in Manitoba, Canada, as well as the adaption planning, the chapter attempts to provide a pattern and workable recommendations for other ports and port supply chain development in adapting to climate change. It is also noticeable that this five-part approach to climate change adaptation planning illustrates several important factors in implementing an effective adaptation plan (Proposition 2 in Chapter 2). For instance, it emphasizes balance and prioritization of the trade-offs among different parties and as well as the broad collaboration between internal and external stakeholders in the port supply chain.

5.2 CentrePort Canada

5.2.1 Flooding in Manitoba

CentrePort is a 20,000-acre inland port in Winnipeg, Manitoba. Located along the longitudinal centre of Canada, it aims to become a hub for trade and transportation corridors, connecting Canada to major markets, such as the US, Mexico, Latin America, Europe and Asia (CentrePort Canada, n.d.a). While enjoying strong transportation and economic and infrastructural support from the provincial government in the city of Winnipeg, CentrePort as a part of the community also shares the risks and uncertainties posed by climate change involving the city and its transportation network. One of the most significant risks is flooding along the Red River Valley. As a tri-modal (rail, road and air) inland port, although there is no confirmed evidence that CentrePort has been severely affected by flooding, it is recognized that CentrePort is vulnerable to the risks of flooding in highway, railway and air transport[1].

The flooding history of Manitoba can be traced back to the 1800s. There were four exceptional events that took place in 1950, 1997, 2009 and 2011 respectively in the areas of the Red River, Assiniboine River and Saskatchewan River (Government of Manitoba, 2014b). The impacts of flooding in the past century were wide-ranging and far-reaching in ground water, surface water, livestock, crops and farm property, as well as the transportation system. For instance, the recent flooding on the Assiniboine River and Lake Manitoba in 2011 was expected to create the highest water level in the past 330 years. This one-in-2000-year event (e.g., Owen, 2012) resulted in "the closure of 850 roads, including part of the Trans-Canada Highway"(Government of Manitoba, 2014b). Meanwhile, "Highway 75 in major floods of the Red River has been cut off for a month, so the supply chain is disrupted for a month (interviewee 2, July 24th 2014)", which interrupted the flow of cargo between the United States and CentrePort and impacted further demand and supply between Southern and Northern Manitoba. The reasons for these floods are complex and varying from year to year. The flooding could be attributed to a heavy rainstorm in spring or melting heavy snow water during the previous winter. Also, a heavy storm or tornado in summer would increase the possibilities and intensities of floods (Government of Winnipeg, 2014).

Unsurprisingly, the Manitoba government has adopted a series of policies and action plans since the 1950s involving fighting and compensating floods. "Flood Fighting in Manitoba" (Government of Manitoba, 2013) illustrated the background and reviewed the

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[1] Interviewee 1, July 15th 2014

history of Manitoba's flood protection. The main flood control structures for protecting the City of Winnipeg include the Red River Floodway, the Portage Diversion and the Shellmouth Reservoir. One of the most significant measures for CentrePort is the Red River Floodway, which was built in 1968 and expanded in 1997. It contains the Assiniboine River Primary Dikes, the West Dike, and the Red River Primary and Ring Dikes. Starting in 1997, more than USD1 billion has been invested in flood mitigation and control, which effectively prevented over USD7 billion in damages throughout the province of Manitoba (Government of Manitoba, 2013). Since 2005, a USD665 million investment in expanding and excavating of the floodway channels in the Red River Floodway has greatly helped minimize damages in communities, agriculture lands and the transportation network. At the same time, a relatively complete forecasting (by Hydrological Forecast Centre) and strong emergency management system (by a partnership led by Manitoba Emergency Measures Organization (EMO) and MIT) with top-down mitigation acts and enhanced training, infrastructure and equipment has been contributing to protecting Winnipeg and CentrePort from the risks posed by the unprecedented flood in 2011.

Nevertheless, Manitoba is still facing dilemmas caused by flooding. As an Alberta emergency management summit in 2013 titled "flood mitigation through innovation: a Manitoba perspective" summarized, there are difficulties in predicting flooding in particularly severe climate change conditions. Additionally, since investment in flooding mitigation always has a long-term return, it is necessary for investors and decision makers to consider a variety of factors including return on investment, protection standards, and the anticipated frequency and intensity of floods. Understanding such situations, it might suspect that

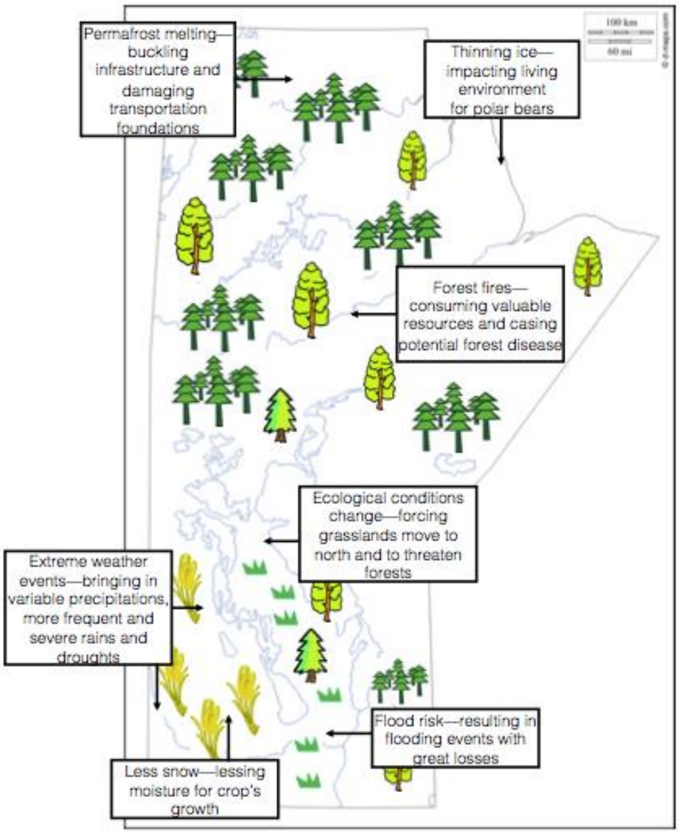
CentrePort is still confronted with similar flooding challenges posed by climate change as the city and province. Thus, a specific adaptation plan for climate change in CentrePort is considerable from the flooding perspective.

5.2.2 Uncertainties and current measures

Apart from flooding, it is also worth noting that the climate change impacts for the central area of Manitoba published on the Government of Manitoba website (Figure10) include *more extreme weather events* (e.g., tornadoes, heavy storms, extreme cold events, longer and frequent droughts might effect port operation), *variable ecological conditions* (e.g., grassland would move to northern areas so as to edge out boreal forest which might increase the severity of flooding risks), as well as *significantly less snow cover* (which could lead to less moisture for agriculture which in turn might indirectly impact the port's business) all introduce uncertain elements for CentrePort (Government of Manitoba, 2014a). Moreover, the climate change events happening in other jurisdictions might trigger variations and uncertainties in the traffic and business of CentrePort due to the domino effect on the supply chain. For example, floods, tornadoes and hurricanes in other Canadian seaports as well as the United States might impact freight movement by rail, road and air networks, as well as delay the transport schedule and damage the infrastructure in all the supply chains that CentrePort has involvement with[2].

[2] Interviewee 2, July 24th 2014

Figure 10: The potential impacts of climate change on the Province of Manitoba (Source: Government of Manitoba, 2014；Blank map source:d-maps.com)



Fortunately, the Manitoba government has been pursuing relatively holistic policies and initiatives to handle climate change impact in the past years. "Tomorrow now: Manitoba's green plan" is a recent provincial government document released in June 2012 to guide green economic activities till 2020. One of the highlighted themes is climate change, which contains both mitigation and adaptation initiatives to prepare and prevent climate change impacts in Manitoba. This important guide provides for a wide range of public participation from municipalities, environmental organizations, industry associations, and academics as well as households. For the new mitigation plan, Manitoba attempts to utilize a comprehensive strategy in reducing Greenhouse Gas (GHG) emission by encouraging stakeholders to get involved in the new plan, enhancing the mandatory reporting of GHG emission, establishing a new biomass economy network, activating a transportation strategy etc. Simultaneously, the adaptation plan stresses the collaboration, attention and innovation from the whole of society, and the “pathway” is divided into three phases from governmental-wide risk assessment and province-wide risk assessment to adaption strategies and action plans. Considering that climate change impacts on transportation arise from various sources, it might be suggested to focus on multiple areas in this guideline. For example, for flooding issues in Manitoba, it might need to consider disaster prevention, prediction and monitoring (e.g., by “ Light Detection and Ranging (LIDAR) data acquisition” mapping and analyzing techniques and water retention and storage measurements), as well as infrastructure upgrading (e.g., sustainable drainage and green infrastructure) in water management.

Although CentrePort has considered climate-change factors in its business plan (including anti-flooding measures in developing the common-use rail facility and modernizing the highway network and infrastructure, and green sustainable philosophy in reducing GHG and encouraging rail usage), this inland port was established in 2011 and is mainly focused on facilitating investment, regional economics and employment, and promoting and marketing itself in Canada, North America and around the world (CentrePort Canada, 2015).

5.2.3 Adaptation planning

It is obvious that there is a lack of attention and specific planning on how to adapt to uncertainties posed by climate change at CentrePort and in the port supply chains overall from both the corporate and government perspective. The factors that require attention include financial budgets and lower-priority awareness among other factors. The chapter argues that an adaptation plan for climate change considering the flooding risks and other uncertainties is very necessary for CentrePort, and will greatly contribute to realizing the objectives of CentrePort's forthcoming five-year plan (2015-2019) and developing a strategic inland port. The authors will analyze the necessity, as well as the strengths and weaknesses of adaptation planning for climate change at CentrePort in the following context.

First of all, from the political perspective, adaption planning accommodates the demand for sustainable and green development of the provincial, federal government and international society. Adapting to the impacts of climate change requires open information exchange and communication between internal (CentrePort) and external audiences (municipal politics, international institution, public, etc.). The governmental initiatives for climate change impact environmental policies ("Tomorrow now") and investment in transportation infrastructure (e.g., Highway 75, Centre Canada Way) plays a vital role in guaranteeing the traffic safety of CentrePort. Meanwhile, the feedback from CentrePort and its customers in operations and utilization are equally important to modifying and improving the higher-level plans. Therefore, an adaptation plan for climate change at CentrePort will greatly help to bring higher-level knowledge to CentrePort and also provide information to governments regarding its environmental plans.

Most importantly, an adaption plan for climate change would be related to the strategic priorities in CentrePort's five-year plan. For instance, the adaptive flood-proofing measures will minimize the risks in the common-use rail facility in order to facilitate cargo security and efficiency and inland port management. Furthermore, because any chains are only as strong as their weakest link and the uncertainties posed by climate change on CentrePort will impact the efficiency of the supply chain in either a direct or indirect way, an adaption plan which attempts to minimize the risks and uncertainties posed by climate change and maximize the benefits to the relevant stakeholders (the customers, partners, suppliers) will boost marketing and investment promotion in the long run.

There are resources available to support the development and implementation of an adaptation plan for climate change at CentrePort. First, the corporation itself possesses advantages from provincial and municipal governments in terms of funding and infrastructure assistances. In 2013-2014, CentrePort Canada Inc., based on the funding agreements, has received USD517,880 from the provincial government and USD1,284,800 from Western Economic Diversification, and those numbers are expected to continually increase in 2014-2015 (CentrePort Canada, n.d.b). The relatively rich budget will allow the corporation to become financially self-sufficient by 2017 and make an adaptation plan for climate change in the future. In addition, government investment in main transportation infrastructure including Highway 75 and the newly constructed CentrePort Canada Way have already taken some climate change factors into account (e.g., flood-proof designing), and have laid a solid foundation for creating an adaptation plan at CentrePort.

As an inland port largely connected by trucks, CentrePort is less vulnerable to climate change risks than seaports that mainly depend on shipping and rail. Given that the tri-modal transportation network is attributed to multiple partnerships with Bison Transport, Manitoba Infrastructure and Transportation, Canadian Pacific Railway (CPR), Canadian National Railway (CNR), Boeing and Winnipeg James Armstrong Richardson International Airport etc., an adaptation plan for climate change at CentrePort will benefit from the experiences and achievements of these cooperating entities in adapting to the impacts of climate change. For example, technical and engineering expertise could be provided by different entities such as MIT, and the Manitoba Trucking Association (MTA).

Although the importance of adapting to the impacts of climate change on the transportation sector has only begun to be appreciated by companies and governments in the past few decades, there have been a considerable number of studies and discussions on the relevant topics in Manitoba. For instance, a workshop titled “Transportation & Climate Change in Manitoba” (presented by University of Manitoba Transportation Institute for Manitoba Government and Transportation Services in February 2013, Winnipeg) has summarized some significant impacts of climate change on Manitoba’s transportation industry (e.g., the risks of melting permafrost on remote communities and the opportunities of winter roads on Port of Churchill), the mitigation measures on reducing GHG emissions in transportation-related areas, as well as adaptation initiatives (e.g., climate change damage tolerant infrastructure) at industry as well as Provincial and Federal Government levels. Also, a recent initiative project “Climate Risk Assessment of Transportation Requirements for the Manitoba-Nunavut (MB-NU) Supply Chain” as representative research in the relevant fields, is providing valuable references for establishing an adaptation plan for climate change in the CentrePort and Hudson Bay Railway supply chain[3]. For instance, the risk-assessment tool PIEVC in examining climate vulnerabilities for major forms of transportation infrastructure

[3] Interviewee 3, July 31st 2014

used to connect Northern Manitoba and the Kivalliq Region could be considered in the case of CentrePort.

5.3 Hudson Bay Railway

5.3.1 Introduction

Climate change is a two-edged sword, creating opportunities along with new challenges for OmniTRAX Canada, owner and operator of the Hudson Bay Railway and Port of Churchill in Northern Manitoba, Canada. The Hudson Bay Railway connects the Canadian National Railway to the arctic deep water Port of Churchill, transporting commodities such as grain, lumber, and petroleum as well as other essential goods to northern communities. Although climate change is responsible for longer shipping seasons and access to previously impassable waterways such as the Northwest Passage, it is also creating unique challenges for the railway that is operated by this company.

5.3.2 The problem

The Hudson Bay Railway was laid over permanently frozen peatland, which has high water content and becomes very unstable when thawed, unlike bedrock, which provides a stable base whether it is frozen or not[4]. The frozen peatland actually serves as an insulating layer, keeping the ground permanently frozen and relatively stable. During construction, portions of this insulating layer were excavated and removed to even the surface while the track was laid[5]. Actions such as this allow summer heat to penetrate into the permafrost and allow the peatland to melt and become active, reducing stability dramatically.

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4 Interviewee 7, August 11th 2014
5 Interviewee 7, August 11th 2014

Also adding to the stability issue faced by the Hudson Bay Railway are the effects of climate change. Permafrost, the type of ground that the railway sits on, remains frozen for at least two consecutive years (Weather Underground, 2014). The top layer of permafrost is known as the active layer, which has been known to thaw in summer. Increased temperatures due to climate change have caused previously inactive areas of permafrost to become increasingly active, resulting in larger areas of permafrost that are susceptible to thawing in the summer months (Weather Underground, 2014). This phenomenon is partially responsible for the increasing instability of the Hudson Bay Railway.

5.3.3 The impacts

The resulting impact of the unstable railway has resulted in an overall lack of reliability. Recent derailments have caused supply chain interruptions, resulting in delayed shipments to the Port of Churchill that proved costly due to the lack of alternate routes. These interruptions extend beyond delayed movements of goods to Port and essential supplies to Northern communities. Aside from costly air travel, the railway is the only way for passengers to move between Churchill and the more populated areas of Southern Manitoba. The Hudson Bay Railway provides a crucial connection for people residing in Northern Manitoba. Recently, a derailment of thirteen-grain cars resulted in cancelled passenger service to and from the town of Churchill (Canadian Broadcasting Corporation, 2014).

Even when the railroad is open, slow travel speeds are often required due to uneven and heaving track. This can result in a journey that is relatively rough for passengers, and makes it difficult to transport much of anything other than bulk commodity goods. The lack of stability and reliability of the rail line has recently been cited as a reason for disapproval by

Government and interest groups of a proposal by OmniTRAX to transport large quantities of petroleum to the Port of Churchill via the Hudson Bay Railway (Canadian Broadcasting Corporation, 2013).

5.3.4 The current plan

Rail upgrades have recently been undertaken to remedy the stability problem. OmniTRAX claims to have invested nearly USD110 million in recent track upgrades, with an additional USD40 million contributed by the Provincial and Federal Governments (Winnipeg Free Press, 2014). Significant money was spent to enhance the stability of the bed itself, particularly in the area stretching between the town of Churchill and Gillam, Manitoba[6].

Although the Hudson Bay Railway is privately owned and operated, it serves as the main connection between the remote areas of Northern Manitoba and the more densely populated areas of Southern Manitoba for passengers and goods. Despite private ownership, this railway has certain aspects of a public good. The railway was built and operated by the Canadian National Railway until 1997, when it was privatized and portions of rail were sold. Although the railway is now owned and operated by the private sector, the Provincial and Federal governments still have an interest in keeping the track operational due to the number of citizens that rely on the railway.

5.3.5 The need for an adaptation plan

An adaptation plan should be developed to cope with the negative impacts of climate change while simultaneously providing an outcome that also makes use of the opportunities that climate change can provide. In this case, an appropriate plan would allow OmniTRAX to

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[6] Interviewee 6, August 14th 2014

operate the Hudson Bay Railway despite the increasing destabilization of the ground beneath the tracks as well as provide the company with an opportunity to make use of longer shipping seasons and access to new routes through the Port of Churchill.

Conceptually, two approaches come to mind, the first of which is excavation. Removing the peatland that makes up the layer of permafrost that consists of high water content and replacing it with a course material such as crushed rock could increase stability temporarily; however, it would also allow warm summer temperatures to have an access route to penetrate the frozen ground by removing the insulating layer of earth, ultimately resulting in reduced stability. This would likely impact the areas surrounding the tracks negatively, and would be an expensive undertaking regardless. This is not, therefore, a practicable solution.

The second approach would be to lift the track and lay an insulating bed of gravel that might reduce the way in which heat can penetrate the top layer of permafrost[7]. Although this is not a permanent solution and would require regular maintenance of (and addition to) the gravel bed, this solution might reduce the negative impact on the surrounding environment and allow the railroad to operate more reliably.

Currently, a formal adaptation plan has not been officially developed. OmniTRAX and the Churchill Gateway Development Corp are working with universities to study climate change and the impact on the Port and the railway[8]. The majority of the research is focused on determining predictability of the changes. Once predictability can be adequately determined, a comprehensive adaptation plan will be put in place.

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7 Interviewee 7, August 11th 2014

8 Interviewee 6, August 14th 2014

The plan will be focused on dealing with the negative impact that climate change has forced onto the railway. The primary focus will involve improving the rail bed to increase stability and reliability to allow the owner to shift attention to the secondary focus, which is to determine how to utilize the opportunities provided by climate change to their advantage. Currently, advantages provided by the longer shipping season opportunity are difficult to achieve due to insurance restrictions for vessels travelling to and from the Port of Churchill outside of the regular shipping season[9].

5.4 Discussions and Recommendations

Even with the above resources in both case studies, barriers and dilemmas stand in the way of making adaptation plans for climate change. The most concerning issue is the financial constraint: there is a constant negotiation between the public and private sector on who pays for reducing risks. Ultimately governments, public organizations, private entities (e.g., CentrePort itself), and co-investors are responsible, but for what percentage? For CentrePort, within a tight budget, how much and at what exact time point should it spend for the future on resiliency, on preparing for 1-100 year or 1-300 year events? At the same time, macrocosmically, there is little doubt that adaptation planning is necessary and becoming increasingly important with more attention and help being given. However, when institutional guidelines are lacking, how can the high-level knowledge be downscaled into corporate plans and businesses?

Since this adaptation plan at CentrePort will involve almost every stakeholder in the supply chain (i.e., Manitoba governments, OmniTRAX, The port of Churchill, the town of

[9] Interviewee 6, August 14th 2014

Churchill, the first nation communities along the rail line from Thompson to Churchill, the University of Winnipeg and other academic institutions, as well as Manitoba Hydro and other partners of CentrePort), the next challenge is how to analyze the trade-offs among different stakeholders, and prioritize and maximize the benefits of the whole supply chain.

In the case of the Hudson Bay Railway, does a privately owned transportation mode that is relied upon by an entire community warrant government intervention and funding to ensure proper maintenance, safety, and reliability? Although climate change is not just a Government or private sector issue, at what point does maintenance of a privately owned good become the responsibility of the public sector?

In the case of CentrePort, it is noticeable that because adaptation planning is in the conceptual stage, it needs to draw advanced experiences and suggestions from similar inland ports when adapting to climate change risks and uncertainties. However, as CentrePort has its own unique geographic and vulnerable conditions for climate change, accommodating the planning of others into its own pattern is another question that needs to be considered.

Last but not least, a successful adaptation plan is always in line with high public participation， which is universally recognized in policy responses to climate change (Few, Brown and Tompkins, 2007). Recent research on adapting to climate change on a coastal area in Britain described the significance of effective public participation, including, in particular, local participation, as an important consideration in decision-making of adaptation planning (IISD, 2003; Willows et al., 2003). Nevertheless, since climate change is not the priority in the public mind nowadays, it would be difficult to collect information in the initialization stages of the plan, as well as to maintain and upgrade information after the plan has been implemented. Thus, how to increase the public participation rate and diversify the sources of participation should be taken into account in long-term adaptation planning.

When conducting adaptation planning, it must be noted that climate change is not simply a public or private sector issue; it is an issue that impacts all parties, and therefore all parties must work together to adapt. Our recommendation consists of a five-part approach to climate change adaptation planning.

Part one involves increased awareness and understanding of the challenges and risks imposed by climate change. Specific guidelines must be set by governments and interest groups to guide adaptation planning. Part two consists of transparency and openness when sharing information regarding the magnitude of the risks. Lack of cooperation can result in expensive redundancies and reduce the overall effectiveness of planning.

Part three considers balancing and prioritizing the trade-offs between all of the relevant stakeholders. Trade-offs should be balanced in a way that maximizes the outcome and interests for the parties involved. The fourth part consists of utilizing information from the experiences of other ports in similar situations. Although these experiences not be directly applicable to the Port in question, they can often provide valuable information when conducting adaptation planning. It is important to adjust the plan to the local situation. Applying the experiences of other similar ports will help to create a plan that is relevant and useful.

The fifth and final part involves participation in decision-making. All of the relevant stakeholders, whether they are governments, industry groups, private sector firms, or environmental groups, must be involved in the decision-making process to ensure that the interests of each party are represented and all parties buy into the process.

It is our recommendation to utilize this five-step approach in order to determine an adaptation plan that accurately represents the issues addressed in this study as well as the interests of all parties involved. Although specific suggestions have been listed above, further research is required before an effective adaptation plan can be implemented to deal with the negative and positive aspects of climate change.

5.5 Conclusion

With the strengthening of adaptation strategies for climate change, the development of ports and port supply chains requires information from worldwide advanced experiences in further adapting to the impacts of climate change. This chapter focuses on climate change and adaptation of transportation and supply chain infrastructures in Manitoba, Canada. By using two case studies, namely CentrePort and the Hudson Bay Railway, it examines the way climate change is influencing the port and port supply chains in both positive and negative ways. The Provincial and Federal governments have undertaken relevant action plans and initiatives and considerable infrastructure investments in both cases. Given favorable flooding prevention and protection from governments, CentrePort has started with a high standard in adapting to flooding as a primary risk posed by climate change in Manitoba. Simultaneously, rail upgrades have recently been undertaken to remedy the stability problems of frozen peatland and permafrost posed by climate change. However, both of the cases failed to realize the potential uncertainties (i.e., tornadoes, heavy storms, extreme cold events) posed by climate change on the inland port or railway itself and stakeholders in the supply chain. Based on the exploratory interviews conducted in the two cases, it is found neither CentrePort nor Hudson Bay Railway has a specific adaptation plan for climate change, which is mainly attributed to the deficiencies of top-down policies, prevention awareness as well as advanced experiences in adapting climate change uncertainties.

Understanding the above situations, this chapter encourages the establishment of an adaptation plan for climate change in the supply chains of CentrePort and Hudson Bay Railway, by analyzing the needs and resources in the two entities. Furthermore, focused on the common dilemmas in the trade-offs between stakeholders, public participation and other topics in adaptation planning, it triggers more discussion and provide workable recommendations for other ports and port supply chain development in adapting to climate change.

Chapter Six: A Study of Implementing and Improving Adaptation Planning in Coping with Climate Change Impacts on Ports of Montreal

6.1Introduction

With the tendency of global warming, the climate in Great Lakes is changing. It is noticeable there are shorter winters, lesser ice cover with an increasing annual temperature over the past three decades (Kling, 2005; State of Lakes Ecosystem Conference, 2006; Austin and Colman, 2007). Consequently, the average temperature in the Great Lakes basin is estimated to increase by about 4.5 ℃ by 2055. Faster evaporation and drier soils would decrease runoff so as to lower the water level by an average of 0.5 m-1.0 m in typical scenarios and to reduce the water column by 20% (Charron et al., 2004). Together with the uncertainties from extreme weather and unstable precipitation (e.g., hurricanes, high winds, heavy rain and snow, less ice cover), US and Canada demonstrate a lower possibility in lake levels in Great Lakes since 1980's[10] (Quinn, 2002).

As the cargo volume that a ship can carry mainly relies on the minimum depth of water level in the navigation channel and a vessel's squat, the issue of lower water level in St. Lawrence River would significantly affect the varied aspects of Port of Montreal whose water partially supplied by the Great Lakes. "What happened historically is that 2 years ago, water level of St. Lawrence dropped by 2 cm, but the industry adapted by sending more ships of smaller size"[11], which deteriorated the port's operation and increased additional costs. Meanwhile, once the lower water level situation exceeds standard, the port would consider renewing the facilities and transport infrastructure to adapt to the climate change. From the

[10] Interviewee 9, January 12th 2015
[11] Interviewee 10, January 12th 2015

perspective of port stakeholders, since carriers will impose USD 200 surcharge per container on the shippers when the vessels cannot be filled in a low water level condition, the butterfly effect of increasing cost will finally pass downstream to the customers and deteriorate the current advantages of Port of Montreal compared to port of New York and other competitors [12]. Moreover, if lower water level restrain the shipping business, containers may need to be stocked somewhere inland until the water level arise, at the same time, more freight and rail would be supplemented. Both of the effects will subsequently boom the costs and modify the transport pattern of the entire port supply chain[13].

A considerable amount of efforts has been taken to minimize the risks of lower water level in St. Lawrence River and Port of Montreal. For instance, there are efforts including the economic impact analysis by simulating climate change scenarios ("Low Water Blues" (Shlozberg et al., 2014)) and data collection and forecasting supported by International Joint Commission (IJC), Environment Canada cooperated the Canadian Hydrographic Service and the Canadian Coast Guard (Port of Montreal, 2015e). Most importantly, for deepening the navigation channel, dredging has been carried out between Quebec City and Montreal on four times since 1883. Nowadays, thanks to the innovation of electronic navigation supported by the Dynamic Under-Keel Clearance System (DUKC®), users are able to collect more precisely real time data in order to ensure that the port has operated under the minimum under keel clearance. Port of Montreal attempts to promote the electronic navigation to the shipping lines, carriers, terminal operators, train companies (e.g., CN, CP) and all the related stakeholders to delay or minimize the possibility of capital dredging in the future.

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[12] Interviewee 10, January 12th 2015

[13] Interviewee 10, January 12th 2015; Interviewee 11, January 13th 2015

Nevertheless, the current adaptation planning for climate change is still relatively untouched. There are a few dilemmas may need to be considered in a long-term adaptation plan. The first problem stems from the uncertain timespan of the adaptation planning. Second, even though the Port of Montreal has initiated risk-analysis procedures, there lacks a specific risk-analysis system for climate change. Third, the decision-making and implementation of the adaptation plan is mainly based on top-down approach. Finally, for existing adaptation scheme of electronic navigation, once the conditions of climate change become severe, it can only be regarded as a transit plan to delay capital dredging.

The chapter mainly investigates the risks of lower water level and other uncertainties posed by climate change in the Great Lakes-St. Lawrence system (GLSLS) and Port of Montreal, as well as the adaptation strategies utilized to cope with the lower water level issues in this area. The contents of the chapter are based on the several interviews undertaken with the relevant stakeholders in the supply chain, corporate documents and governmental policies (see Chapter 3).

The author identifies the climate change risks (lower water level) and other uncertainties of the extreme weather events (e.g., hurricanes, high winds, heavy rain and snow, less ice cover) on port operation, supply chain interruption and transportation patterns and infrastructure on Port of Montreal by positioning it as an industrial heartland in North America. Afterwards, it focuses on the adaptation planning in the Port of Montreal and analyzes the advantages and dilemmas involved in, the current planning process. By doing so, this chapter proposes a three-part improvement scheme, via taking the advantage of current adaptation resources, resolving the current planning dilemmas and constructing alternative adaptation measures, to encourage more attention to, and discussion of, detailed issues (such as public participation and insurance) in adaptation planning. Through examining climate change and adaptation of Port of Montreal, Canada, as well as improving the existing adaption planning, the chapter provides an innovative thinking pattern and workable recommendations for other ports in adapting to the risks and uncertainties posed by climate change.

Similar to the method of analyzing the case of Manitoba (Chapter 5), the analysis procedure for Port of Montreal is also in line with the generation of an adaptation plan (Proposition 1 in Chapter 2), which starts from identifying the low water level issue and other uncertainties and risk prediction and economic impact analysis, examining the advantage and barriers in current adaptation planning to offering recommendations for improving adaptation planning. Meanwhile, in investigating the important factors in adaptation planning, besides enhancing the collaboration between internal and external stakeholders (Proposition 2 in Chapter 3), the author encourages to draw the port own experiences, strengthen the forecast of climate change, construct alternative approachable strategies.

6.2 The Risk of Lower Water Level in Great Lakes-St. Lawrence System

6.2.1 The Port of Montreal and the Great Lakes-St. Lawrence system

Port of Montreal, within its strategic location of 1,600 km inland from the Atlantic Ocean, is one of the important ports along the East Coast in North America. It has become an industrial heartland in North America and providing fast channels and economical service to Central Canadian and major North American markets. The developments were supported by modern facilities to handle all types of cargo with 1.3 million TEU, as well as the strong links with global ships, trains and trucks. The Port of Montreal develops into an integrated intermodal hub to get access to more than the ports among over 100 countries, especially to major North European and Mediterranean ports, e.g., port of Liverpool, Rotterdam and Antwerp (Port of Montreal, 2015b).

The Great Lakes-St. Lawrence system (SLGLS) covers approximate 20% of the world's surface fresh water and has been playing a pivotal role in catalyzing the bilateral trade between two Canadian provinces and eight U.S sates since they were combined to open the longest deep-draft navigation system in the world in 1959 (Port of Montreal, 2015c). This system contains 15 locks (two US and five Canadian locks form Montreal to Lake Ontario, as well as eight Canadian locks in Welland Canal), and 15 short canals and channels (Great Lakes Saint Lawrence Seaway System, 2015c). Port of Montreal stretches for more than two km along the St-Lawrence River in old Montreal and is officially the Eastern inlet to the St. Lawrence Seaway. Thus, the Great Lakes-St. Lawrence River and the entire seaway system (Saint Lawrence Seaway, 2015b) is inherently connected the water management of Port of Montreal. As the management of huge reservoir involves in diverse regions between Canada and U.S, and to prevent and solve the disputes of water-related issues between the two countries, The International Joint Commission (IJC) was established in 1912 in lined with the Boundary Waters Treaty signed in 1909. One of the most important missions of IJC is to guarantee that the water level in St. Lawrence will be kept in a natural level (Port of Montreal website, 2015c).

6.2.2 The lower water level issue

With global warming (e.g., Cox et al., 2000), The climate in Great Lakes is changing. It is noticeable there are shorter winters, lesser ice cover with an increasing annual temperature over the past 30 years (Kling, 2005; State of Lakes Ecosystem Conference, 2006; Austin and Colman, 2007). Together with the impact from unstable precipitation of snow and rain, US and Canada projected a possible falling water level in lake levels in Great Lakes since 1980's[14] (Quinn, 2002). The two episodes of lower water level are from 1963 to 1966 and 1997 to 2001 during the past four decades (Quinn, 2002). The lower water level affected a few regional main industries via decreasing the tonnage per trip and increasing the number of trips to higher costs as well as causing traffic backup. For instance, in 2001, the Dry Bulk Commerce declined by 6.7% with 5-8% less commodities than 2000 (Lake Carriers Association, 2002).

Simultaneously, as Great Lakes are the supplier of St. Lawrence River, Environment Canada (2015) is concerned about the lower water level issue in the St. Lawrence River. From 1985 to 1991, as the temperature in Great Lakes area went up by 0.7 ℃, there was declined flow through the mouth of the Great Lakes to the St. Lawrence River and its outlet. It is evident that the episodes of low flow occur around every 30 years, which punctuated with the lowest flow of 6,093 and highest of 20,343 cubic meters per second in 1965 and 1976 respectively (Bouchard and Morin, 2000). Consequently, the average temperature in the Great Lakes basin is predicted to increase by about 4.5 ℃ by 2055; faster evaporation and drier soils would decrease runoff so as to lower the water level by an average of 0.5 m-1.0 m in typical scenarios and to reduce the water column by 20% (Charron et al., 2004). Once the

[14] Interviewee 9, January 12th 2015

situation becomes severer with no adaptation being implemented in the future, it is expected to suffer from the expanded costal areas and the drier wetlands, worse water quality thanks to the lessened dilution of pollutants, increasing concentrations of suspended particulate matter, and the potential relocation of sedimentation zones (Environment Canada, 2015).

For the Port of Montreal, as the cargo volume that a ship can carry mainly relies on the minimum depth of water level in the navigation channel and a vessel's squat, the issue of lower water level in St. Lawrence area would affect the port significantly. "What happened historically is that two years ago, the water level St. Lawrence River dropped by 2 cm, but the industry adapted by sending more ships of smaller size"[15], which deteriorated the port's operation and increased operational costs. Meanwhile, once the lower water level situation becomes severe, the port would consider renewing the facilities and transport infrastructure to adapt to the climate change. From the perspective of port stakeholders, since carriers will impose USD200 surcharge per container on the shippers when the vessels cannot be filled in a low water level condition, the butterfly effect of increasing cost will finally pass downstream to the customers and deteriorate the current advantages of Port of Montreal compared to other competitors (e.g., Port of New York). Moreover, if lower water level restrain the shipping business, containers may need to be stocked somewhere inland until the water level arise, at the same time, more freight and rail would be supplemented. Both of effects will subsequently boom the costs and modify the transport pattern of the entire port supply chain[16].

6.2.3 Water level prediction and economic impact analysis

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[15] Interviewee 10, January 12th 2015

[16] Interviewee 10, January 12th 2015; Interviewee 11, January 13th 2015

Fortunately, lower water level issue has drawn universal attention from diverse federal, municipal, regional and local institutes with considerable water level prediction and economic impact analyses in the past decades (Moulton and Cuthbert, 2000). Marchand et al. (1988) and Millerd (1996) initially utilized climate change scenarios to estimate the impacts on commercial navigation by combining the Great Lakes hydrological model as well as the water level regulation plan. Afterward, Millerd (2005) developed transient scenarios to specifically analyze the impacts. Millerd investigated that a doubling CO_2 could increase annual transportation costs by 29 % and shipping costs by 13% in a more moderate climate change pattern, which vary with different commodities and routes. “Low Water Blues” (Shlozberg et al., 2014) comprehensively assessed the economic impacts of future lower water level in the Great Lakes and St. Lawrence basin, in particular in sector of commercial shipping and harbors including ports and industries that depend on maritime shipping. Through analyzing the economic impacts under a worst-case lower water level scenario, the report implies that, based on the data in 2012, the total costs of lower water level could reach USD9.1billion and USD18.82 billion over the period through 2030 and 2050 respectively. Especially, the estimated impacts on local shipping industry will occupy 12% (USD1.18 billion) by 2030 and 10% (USD1.92 billion) by 2050 of total economic losses, which is mainly attributed to the damage of shipping capacity.

6.2.4 Other uncertainties and vulnerabilities

Nevertheless, the further prediction for climate change in Great Lakes-St. Lawrence system and Port of Montreal become more difficult due to the several uncertainties posed by climate change. As Slack and Comtois (2015) recently pointed out, there remain uncertain factors in predicting water levels in the future. The imperfect interpretation for the changes happened in the past as well as the imperfect climate models for diverse scenarios mainly result in the difficulties in forecasting the magnitude and scope of the future change of water levels (Slack and Comtois, forthcoming). Thus, all the possible scenarios including lower water level, moderate water level and even high water level, would be taken into account in the future (Shlozberg et al., 2014) with the extreme weather events (e.g., hurricanes, high winds, heavy rain and snow, less ice cover) occurring more frequently[17].

Meanwhile, the direct and indirect impacts posed by these extreme weather events on port operation and infrastructure should be considered when adapting to the lower water level issues from the perspective of port supply chains. There is a consensus that the impact of less ice cover might offset some of the costs bring from the lower water level. There is likelihood that global warming will leads to melting the ice cover in the winter so as to extend the shipping season in some climate change scenarios (e.g., Quinn, 2002). In addition, the longer shipping season would enhance the vessel utilization, delay the activities of ice breaking and reduce the stockpiling period of commodities. All of these impacts will contribute to lowering the costs of port operation. Thus, taking the advantage of ice effects would be a possible approach in dealing with the lower water level issues.

Although there is inadequate documentation specifically describing the impacts of extreme weather on the Port of Montreal, the impacts on the province of Quebec are visible. For instance, the great ice storm of 1998 brought some of the busiest ports (including Port of

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[17] Interviewee 9, January 12th 2015; Interviewee 10, January 12th 2015; Interviewee 11 January 13th 2015

Montreal) "to a frigid, ice-encrusted standstill" (Sean Munger website, n.d.). Subsequently, the snow squall loomed over Quebec in winter 2013. Up to 15 cm snow fell over part of southern Quebec and caused worse driving conditions (The Weather Network, 2013). The freezing rain and ice formation also impacted the shipping condition in Port of Montreal and St. Lawrence River by delaying voyage, shortening navigation period etc.[18]. A recent hurricane "Sandy" swept Canada on October 29 and October 30 in 2012 and resulted in heavy rain and snow, high winds in Ontario, Quebec and the Maritimes. Also, as the largest storm ever to hit the U.S., when the hurricane shut down the American transit system, it also indirectly influenced the transportation and trade between Canada and U.S. and the entire supply chains (National Post, 2012). However, as these extreme weather events are varying and occur uncertainly and the real economic data is hard to estimate through a quantitative method, relevant research and countermeasures have not been given enough attention.

6.3 Adaptation Planning for Climate Change in Port of Montreal

6.3.1 Current protection and adaptation measures

Unsurprisingly, the existing adaptations for climate change in Port of Montreal mainly focus on tackling the risk of lower water level. The first step is to collect the precise real-time data of water levels. In line with the guideline of water management of IJC and in cooperation with the Canadian Hydrographic Service and the Canadian Coast Guard, Environment Canada has involved in the prediction of water levels for the forthcoming weeks. After collecting the relatively exact data about how deep of the water level, the shipping lines will be informed to determine the date of departure, the tonnage per vessel and other

[18] Interviewee 9, January 12th 2015; Interviewee 10, January 12th 2015

information (Port of Montreal, 2015c). The scientific forecast will allow the shipping lines, carriers, terminal operators and other stakeholders to acquire the data taking within one to two weeks so as to adjust their business with commission[19].

Dredging, as one of the most common adaptation strategies for deepening the navigation channel, has been carried out between Quebec City and Montreal on four times in 1883, 1910, 1992 and 1999, which increases the minimum depth of the channel from 7.5 meters in 1883 to 11.3 meters in 1999 (Port of Montreal, 2015a). The primary purpose of the dredging work was to meet the demand of commercial shipping which tends to accommodate “Panamax” ships[20]， or wider vessels to come to the Port of Montreal (Port of Montreal, 2015f). Additionally, these dredging activities guaranteed the normal operation of the Port of Montreal in the past decades and partially minimized the vulnerabilities of lower water level in the St. Lawrence area at the same time.

However, with the risk of lower water level being increasingly severe, capital dredging would be an inevitable solution in the future. Capital dredging for navigation purpose is “the excavation of sediments to increase depths in an area, usually but not always for the first time, to accommodate the draft of vessels (to a depth that also allows for a siltation buffer zone)” (European Commission Directorate-General Environment, 2009, pp.33). While maximizing the water levels, capital dredging may contribute to a series of institutional, environmental, economic and social problems. First, relatively complex institutional assessments may be required for undertaking capital dredging. For instance, an over 27-foot depth project need to get an appropriation and authorization from federal congress (Quinn, 2002). Generally,

19 Interviewee 9, January 12th 2015

20 “Panamax” refers to definition before the expansion of the Panamax Canal in 2014

capital dredging for deepening navigation channels requires consent under the Harbours Act 1964 (or equivalent local Act) and is subject to the Assessment of Environmental Effects Regulations (UK Marine SACs Project, 2015).

These legislative requirements of capital dredging mainly aims to deal with its two environmental impacts: the dredging process might re-suspend the chemical material (e.g., PCBs, mercury and heavy) buried in the sediment due to the excavation of sediments at the bed; the disposal of the dredged material might jeopardize the water quality, the habitat of benthic animals as well as the living atmosphere and agricultural production of local community (Quinn, 2002). Thus, it calls for a better system to remove the disposal material.

The expensive expenditure for capital dredging is another considerable aspect. Compared with the estimated USD200 expenditure in bringing the dredging system in the Great Lakes in US, the situation in Canadian ports are even more challenging as the majority of expenditure for them stems from the Federal Government (Slack and Comtois, forthcoming). Meanwhile, supplementary measures may need to be considered during the capital dredging. For instance, adding dikes and control systems to prevent the additional lower water level because the channel capacity is increasing (Quinn, 2002), while these additional operations would upgrade the total costs of dredging. Therefore, a cost-benefit analysis needs to guarantee that the dredging program is commercially viable. Finally, the social accessibility is a pivotal issue in conducting capital dredging. The above environmental impacts of dredging may trigger the negative attitude and even conflicts in the riverfront communities. Thus, a long-term local contribution program including financial and other supports should be simultaneously carried out. Accordingly, dredging is proved to be a transitional option during a long-term adaptation planning while all the details benefit of relevant stakeholders need to be taken into account in the early planning stage (Working Group on the Integrated Management of Dredging and Sediments, 2014).

The innovation of electronic navigation is an alternative advanced approach to handle the lower water level. Port of Montreal has been utilizing the electronic navigation technology supported by the Dynamic Under-Keel Clearance System (DUKC®) since 2008[21]. This system allows users to collect the more precisely real time data in order to ensure that the port have operated under the minimum under keel clearance. It is especially efficient for port and waterways to resolve lower water level issues and maximize port productivity and security by considering all factors that effects a vessel passing through the channel (e.g., water levels, wave height, wave period and direction, currents, tidal plane, etc.). This technology allows port administrators to determine the Under-Keel Clearance (UKC) requirements, monitoring the whole transit process and combine the data into transit planning up to 12 months in advance (The Pilot Online Edition, 2013). This international recognized technology has been applied into daily operation of many ports and is especially useful in poor weather conditions (e.g., fog, heavy rain, etc.) and hard-to-navigate narrow sections in St. Lawrence River (Port of Montreal, 2015d). Port of Montreal attempts to promote the electronic navigation to the shipping lines, carriers, terminal operators, train companies (e.g., CN, CP) and all the related stakeholders to delay or minimize the possibility of capital dredging in the future, and this innovative idea would be put into the priority of the future adaptation planning[22].

6.3.2 The advantages of Port of Montreal in adaptation planning

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[21] Interviewee 11, January 13th 2015

[22] Interviewee 11, January 13th 2015

On the basis of above current adaptation measures (dredging and electronic navigation) and the views from interviewees, several advantages in the adaptation planning procedure of the Port of Montreal are summarized. First, as the lower water level issue has been realized in the St. Lawrence area in a relatively comprehensive way, some relevant research (e.g., economic analyses and prediction of lower water level impacts) and action plans (e.g., dredging and electronic navigation) have been undertaken in the past decades. In particular, with the introduction and application of electronic navigation, it is expected to minimize the impacts of lower water level with least costs and in an environmentally friendly way[23].

Second, international, domestic and regional institutes (e.g., IJC, Environment Canada, municipal and provincial government) have initiated a series of regulations or guidelines to adapt to lower water level issues in water management which offers the port available references in decision making. Also, it is noticeable that besides adaptation measures, Port of Montreal has positively involved the mitigation program of Green Marine for mainly reducing GHG emission to realize the greener transportation[24]. Since the reduction of GHG emission is one of the best solutions for decreasing global warming impacts, this action will indirectly contribute to improving the lower water level problem in Port of Montreal in the long-term.

Third, as one of the few ports that have adaptation planning in Canada, Port of Montreal has constructed an elementary risk-analysis procedure. It is yet a comprehensive system but in-house software where for each disciplines, all risks are evaluated as for their severity, impact (such as reputation, financial, human resources, security, productivity, etc.),

[23] Interviewee 8, December 16th 2014; Interviewee 9, January 12th 2015; Interviewee 10, January 12th 2015; Interviewee 11 January 13th 2015

[24] Interviewee 8, December 16th 2014; Interviewee 9, January 12th 2015

recurrence, frequency (probability). For each risk, an action plan is detailed with its implementation timeline. Climate change and its consequences are part of their risk analysis. These risks are attributed to the effect on infrastructure on the public interest and analyzed by the vice-president of operation, vice-president of legal as well as the secretary of the Port of Montreal. As needed, but at least once a year, all risks are re-evaluated by the management team (directors, vice-presidents and president) and the action plan revised accordingly[25].

Last but not least, an ongoing 10-year expanding project of the port terminal at Contrecoeur (Port of Montreal, 2015e) as well as a CAD132 million-investment project focusing on key infrastructure upgrading are expected to increase the port's handling capacity, enhance marine access by deepening the berth and reduce traffic congestion (Lloyd's Loading List, 2015). Both efforts will be beneficial to taking the port's existing advantages in the domestic and international competition while minimizing the potential risks posed by climate change.

6.3.3 The dilemmas of Port of Montreal in adaptation planning

Despite all the efforts on the adaptation planning of Port of Montreal, the current adaptation planning for climate change still needs improvement. There are a few dilemmas may need to be considered in a long-term adaptation plan. The first problem stems from the uncertain timespan of the adaptation planning. Up to date, Port of Montreal is setting a 10-year horizon in an adaptation plan. There is no elaborate reason to warrant the time horizon, however, the 10-year financial plan and 5-year traffic forecast may justify the 10-year horizon for the adaptation plan. Meanwhile, all the factors are considered or will be

25 Interviewee 11, January 13th 2015

considered in making a strategic adaptation plan: the port master plan, environmental plan as well as the experiences of ports that exist the similar climate change issue of the port Montreal, Moreover, the uncertainties of occurrence of extreme weather event shrink the forecasting from a 30-year horizon 50 years ago to beyond 10-year horizon nowadays[26], which consequently results in a short planning cycle for adaptation. The problem of short planning cycle in Port of Montreal is consistent with the research in the complexity in planning: a relatively short planning cycle (10 year) does not correspond to infrastructure lifespan (typically more than 50 years)(ICFI, 2008; Kintisch, 2008; Ng, 2012).

Second, even though the Port of Montreal has initiated risk-analysis procedures, there lacks a specific risk-analysis system for climate change. The current risk analysis is mainly based on the relevant risk management mechanism, as well as safety and security plan etc. Since the procedure is still place at an early stage in the third year, it is too early to judge if it has achieved the expected effect[27]. There is little doubt that a mature risk analysis system should not only consider the risks of lower water level but also other uncertainties posed by climate change. It is necessary to look at both aspects to adapt to potential climate change issues in a long term, but this system might cost around CAD7 billion[28]. Accordingly, the return on investment of a risk-analysis system would be a significant aspect in the further planning.

Third, as this chapter discussed above, although some external supports including financial and infrastructural subsidization from different levels of government, qualification authentication from marine associations (e.g., Green Marine) and academic research from

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26 Interviewee 11, January 13th 2015
27 Interviewee 11, January 13th 2015
28 Interviewee 10, January 12th 2015

colleges and NGOs (e.g., University of Montreal) have been given to adapt to lower water level issues in Port of Montreal, the decision making and implementation of the adaptation plan is still based on top-down approach. Moreover, as a successful adaptation plan is always in line with high public participation, which is universally recognized in policy responses to climate change (Few et al., 2007), especially when the adaptation involves social and environmental accessibility (e.g., in capital dredging). The lack of participation from public and external stakeholders in current decision-making would constrain the port from minimizing the costs, maximize the benefit of stakeholders in the port supply chain (e.g., shippers, carriers, terminal operations) and create a sustainable development environment for Port of Montreal.

Finally, the utilization and promotion of existing adaptation scheme in electronic navigation to a broad range of stakeholders may reduce the risks of lower water level in the near future, but once the conditions of climate change get severe, it can only be regarded as a transit plan to delay capital dredging[29]. Consequently, numerous deficiencies of capital dredging would be re-considered as discussed before.

6.4 The improvement and Discussion of the Adaptation Planning in Port of Montreal

When improving adaptation planning, it must be noted that climate change is not simply issue of one sector; it is an issue that impacts all stakeholders, and therefore all stakeholders must work together to adapt. The accommodation to improve the adaptation planning for climate change in Port of Montreal consists of three parts: taking the advantage of current

[29] Interviewee 11, January 13th 2015

adaptation resources, resolving the current planning dilemmas and constructing alternative adaptation measures.

The research in predicting and adapting the impacts of lower water levels posed by climate change in the region of Great Lakes and St. Lawrence River laid a good foundation in dealing with the lower water level issue as well as arousing the institutional and public awareness for this issue. Further adaptation planning is suggested to continually enhance the public attention and shift the general concerns from water management to broader participation in decision-making. Thanks to the high-level regulation or guidelines in regional water management, Port of Montreal may continually draw the references from own advanced experiences and update the adaptation measures subject to the conditions of climate change within the legislative framework as well as keep the cooperation with Green Marine to mitigate climate change. Also, on the basis of current risk-analysis, more assessments of climate change effect should be taken to modify the inappropriate procedures. Additionally, when designing and implementing relevant projects (e.g., the expending project to Conrecour and infrastructure investment), climate change uncertainties, timespan of infrastructures, return rate of investment and other factors should be taken into account at the early stage.

To relieve the dilemmas in adaptation planning, the first step is to strengthen the forecast of climate change data by state-of-the-art technologies to construct a more reasonable timespan for adaptation planning, which could accommodate the life cycle of infrastructure and other requirements. Meanwhile, introducing an elaborate risk-analysis supported by cost-benefit evaluation would be an approachable plan in the long term. Although the Port of Montreal has encouraged public to involve port affairs and activities (e.g., by creating a community liaison committee and organize regular meetings to discuss various projects (Port of Montreal, 2015g)), there lacks of partnership-collaborative approach in public participation; the public is not really keen on the participation in particular in port planning. The low knowledge of the importance of the port is one of the main reasons might justify the phenomenon. To stimulate the public participation in decision-making, Montreal Port Authority may consider utilizing media coverage (e.g., newspaper, Facebook, Twitter and the port's official website) to enlarge the influence of the port authority and attention on adaptation planning. By doing such, public will not just be consulted but really involved in real planning process. Finally, apart from all the above optimal suggestions, alternative adaptation planning approachable strategies should be put on the agenda due to the imperfection of dredging and electronic navigation.

Current adaptation planning for lower water issue mainly focuses on three aspects: redesigning lock chambers, changing regulation policies of waterway and rerouting shipment in vessel operation (e.g., Millerd, 2007; Quinn, 2002; De Loë et al., 2001). Besides dredging, adding a wider lock chamber is a considerable engineering choice for Port of Montreal in its planning (Port of Montreal, 2015), which is inspired by the designing of 55-meter-wide lock chambers in Panama Canal. The completion of similar lock chambers in Port of Montreal will allow "Post-Panamax"[30] vessels (more than 32-meter-wide) to come through the seaway system without restrictions. Another direct way is to change the regulation of the water level itself, for instance, by adjusting the minimum water level to accommodate the new climate

30 "Post-Panamax" refers to definition before the expansion of the Panamax Canal in 2014

change scenarios so as to guarantee stable vessel flows in a secure condition[31]. Moreover, once the lower water level constrains shipping operation, shipments could adapt to the change of water level through rerouting the pathway and the amount of cargo in a cost-effective strategy. One way is to arrange partial cargo of a vessel to unload at the Port of Montreal and then unload the remainder at a deeper port (Millerd, 2007).

Besides the above three strategies, Slack and Comtois (forthcoming) proposed several alternative adaptation options for SLGLS, including adjusting the loadings of seasonal cargo loadings, relocating the port, shifting transportation modals, widening vessels, etc. However, as Slack and Comtois summarized, each of solutions exist drawbacks and difficulties in implementation. Since many of these potential measures involve technical and engineering solutions, thus, the costs, effectiveness, environmental and accessible issues and other factors should be taken into account in improving adaptation planning for climate change (Slack and Comtois, forthcoming).

6.5 Conclusion

With the strengthening of adaptation strategies for climate change, the development of ports and port supply chains requires information from worldwide advanced experiences in further adapting to the impacts of climate change and improving existing adaptation planning. This chapter focuses on climate change and adaptation of transportation and supply chain infrastructures in Great Lakes-St. Lawrence system (GLSLS), in particular the Port of Montreal Canada. Through in-depth interviews with relevant personnel affiliated with Port of Montreal, the chapter examines the multiple effects of lower water level and other

31 Interviewee 10, January 12th 2015

uncertainties in the port and port supply chains. To date, institutional supports have been provided in water level forecasting, economic analysis and guidelines in adaptation represented by International Joint Commission (IJC), Environment Canada, the Canadian Hydrographic Service and the Canadian Coast Guard (Port of Montreal, 2015e).

Given the above assistance as well as the historical experiences in dredging and recent technology of electronic navigation, Port of Montreal has constructed a complete risk-analysis procedure in adapting to lower water level as a primary risk posed by climate change in St. Lawrence area. However, there remain difficulties in forecasting the magnitude and scope of the future change of water levels (Slack and Comtois, forthcoming); the potential uncertainties (i.e., hurricanes, high winds, heavy rain and snow, less ice cover) posed by climate change have not been paid enough attention in the current adaptation planning. Meanwhile, the dilemmas are mainly attributed to the uncertain planning cycle, the lack of specific risk-analysis system and the low participation of public external stakeholders of the port supply chain.

Based on the exploratory interviews conducted in the case of Port of Montreal, this chapter analyzes the resources and barriers in the current adaptation planning and encourage the establishment of an improved pattern of adaptation planning for climate change in the Port of Montreal and its port supply chain. It summarizes several adaptation solutions for future planning, and suggests planners to comprehensively balance the cost, effectiveness as well as environmental and accessible issues in selecting and improving adaptation options. Furthermore, the related topics including planning cycle, risk-analysis system and stakeholder and public participation in improving the adaptation planning are expected to trigger more discussion and provide workable recommendations for the development of other ports and port supply chains in adapting to climate change.

Chapter Seven: Conclusion

7.1 Conclusion and General Discussion

Climate change has become a critical issue in recent decades, involving a variety of disciplines and posing substantial challenges to ports due to the high vulnerability of ports to the effect of climate change. It is believed that climate change jeopardizes not only the efficiency and profitability of ports and the benefits to publics that depend on the functions of ports, but also the operation of global supply chain and human welfare (e.g., Becker et al., 2013). In particular, under current supply chain theories, ports have evolved from a simple node to occupying a role as a strategic component of the supply chain (Song and Panayides, 2008), which magnifies the impacts of climate change on ports, related stakeholders and industries including tourism, fisheries, manufactories, etc.

Although there has been considerable amount of research on the impacts of SLR, high winds and storm surges on ports and a series of second-order consequences of these events (Hanson and Nicholls 2012; Asariotis and Benamara 2012), there remains a few gaps related to climate change and adaptation planning at ports. First, since most of the focus of the risks of climate change is on seaports, rather than on dry ports (e.g., CentrePort Canada), there has been, up to now, very limited research examining the potential risks or uncertainties of climate change on dry ports. Some of the ports have realized the risks of climate change, but easily ignored the potential uncertainties. Additionally, even for port operators who have taken countermeasures to minimize the impacts of climate change on their ports, some strategic and planning problems still remain. One of the main issues is of climate change strategies. Current research tends to focus on mitigating climate change issues on transport infrastructure and port operation rather than on adaptation measures (Ng et al., 2013a). Existing adaptation strategies have remained segregated and piecemeal. Another issue is that current port planning may not address the climate change impacts adequately. There are several reasons for this: 1) a relatively short planning cycle (typically 5-10 years) does not correspond to infrastructure lifespan (typically more than 50 years), which leads to the complexity in planning (ICFI, 2008; Kintisch, 2008; Ng, 2012); 2) scientific information inadequately matches shorter-range planning horizons in port community (Becker et al, 2012), which prevents the judgment of port planners from the level of impacts; 3) the lack of engineering and design standards to guide decision-making is another barrier for port planners.

On the basis of path dependence theory, and the theoretical framework of port supply chains and port risk management, this thesis fills the above gaps and achieves four main objectives: 1) to emphasize the significance of uncertainties that climate change poses to port planning and to call for more attention by port planners and stakeholders to these uncertainties (O1: Objective 1); 2) to investigate the general situation of climate change and adaptation planning at Canadian ports (O2); 3) to lay a theoretical foundation on initiating and improving adaptation planning of port and supply chains by integrating consideration of climate change risks and uncertainties into ports planning (O3); 4) to provide workable suggestions for global ports planning by drawing from the experiences of Canadian ports (O4). Afterwards, these objectives are realized mainly through a nation-wide survey (Chapter 4) and two case studies (Chapters 5 and 6). Meanwhile, the two primary research questions (1.what are the main impacts of climate change on Canadian ports? 2. What are the major challenges in adapting to climate change for Canadian ports?) are expected to be answered through the survey and case studies.

Chapter 4 offers a broad overview on how ports adapt to climate change impacts in Canada through a nation-wide survey among 26 Canadian port administers. Generally, the results demonstrate that extreme weather (e.g., unpredictable patterns, hot summer, polar vortex, and heavy, less and freezing rain), high winds and storms, as well as seawater level change are the top three impacts on Canadian ports. This result reveals the main impacts of climate change on Canadian ports (answered the first primary research question), and supports the significance of the uncertainties posed by climate change (O1). Specifically, the three hypotheses in this thesis are partial proven, assisting in the quantitative examination of the efficiency of adaptation measures in coping with SLR, storms and risks and uncertainties posed by climate change in the past decade, as well as the differences between seaports and dry ports with regards to these issues (O2 and O3). Adaptations were estimated to have positive effects in minimizing SLR impacts, especially in reducing SLR severity of consequences with relatively low costs, while reducing the likelihood of storms occurring (O3). Thus, it calls for planners to design more effective adaptation measures and increase adaption budget limits in addressing climate change issues (O4). In addition, a systematic evaluation method with scientific information in climate change forecast and adaptation could deal with risk-analysis issues (O4). Finally, cross-department involvement, public participation and external cooperation including consultants, labor unions, shipping lines, dock workers, freights, forwarders, NGOs, terminal operators, port users, local vessel agents and the municipal governments would contribute to prioritizing and developing strategies in planning, policy making and implementation (O4). Thus, the results of qualitative analysis imply that systematic evaluations, precise scientific forecast, cross-department involvement, public participation and external cooperation are some of the major challenges in further adaptation planning (answered the second primary question).

Subsequently, two case studies (CentrePort and Hudson Bay Railway in Manitoba, and the port of Montreal) are conducted based on the semi-structured interviews. Chapter 5 focuses on climate change and adaptation of transportation and supply chain infrastructures in Manitoba, Canada. In the case study of Manitoba, namely CentrePort and the Hudson Bay Railway, Chapter 5 examines the way climate change is influencing the port and port supply chains in both positive and negative ways (O1). The pprovincial and federal governments have undertaken relevant action plans and initiatives and considerable infrastructure investments in both cases. Given favorable flooding prevention and protection from governments, CentrePort has started with a high standard in adapting to flooding as a primary risk posed by climate change in Manitoba. Simultaneously, rail upgrades have recently been undertaken to remedy the stability problems of frozen peatland and melting permafrost posed by climate change. However, in both the situations, the adaptation plans failed to address the potential uncertainties (i.e., tornadoes, heavy storms, extreme cold events) posed by climate change on the inland port or railway itself and on stakeholders in the supply chain. Based on the exploratory interviews conducted in the two situations, it is found neither CentrePort nor Hudson Bay Railway has a specific adaptation plan for climate change, which is mainly attributed to the deficiencies of top-down policies, prevention awareness as well as advanced experiences in adapting climate change uncertainties (O1 and O2). Understanding the above situations, Chapter 5 recommends the establishment of an adaptation plan for climate change in the supply chains of CentrePort and Hudson Bay Railway, by analyzing the needs and resources in the two entities (O3). Furthermore, focused on the common dilemmas in the trade-offs between stakeholders, public participation and other topics in adaptation planning, this chapter provides a basis for more discussion and provides workable recommendations for other ports and port supply chain development in adapting to climate change (O4). Also, Chapter 5 answered the two primary research questions in the region of Manitoba. First, it investigates the impacts of climate change in including the risks of flooding and frozen peatland and permafrost as well as uncertainties of tornadoes, heavy storms, extreme cold events on CentrePort and Hudson Bay Railway respectively. Meanwhile, trade-offs between stakeholders, public participation, information sharing, risk awareness are examined to be the major challenges in adapting to climate change in the future.

On the other hand, Chapter 6 focuses on climate change and adaptation planning of transportation and supply chain infrastructures in the Great Lakes and St. Lawrence River, in particular in the port of Montreal Canada. By in-depth interviews with relevant personnel affiliated with port of Montreal, this chapter examines the multiple effects of lower water level and other uncertainties (e.g., (i.e., hurricanes, high winds, heavy rain and snow, less ice cover and other indirect impacts) in the port and port supply chains (O1). This result corresponds to the regional main impacts of climate change on Port of Montreal (answered the first primary question). To date, institutional supports have been provided in the form of water level forecasting, economic analysis and guidelines in adaptation represented by International Joint Commission, Environment Canada, the Canadian Hydrographic and the

Canadian Coast Guard (Port of Montreal, 2015). Given the above assistance as well as the historical experiences in dredging and experience with recent technology of electronic navigation, the port of Montreal has constructed a relatively complete risk-analysis procedure in adapting to lower water levels as a primary risk posed by climate change in the St. Lawrence area. However, the potential uncertainties posed by climate change have not been given enough attention in the current adaptation planning. Meanwhile, there remain difficulties associated with the uncertain planning cycle, the lack of specific risk-analysis system, and low participation of public external stakeholders of the port supply chain (O2). Based on the exploratory interviews conducted in the case of port of Montreal, the resources and barriers in the current adaptation planning are analyzed and suggestions are proposed so as to improve the existing adaptation planning for climate change in the port of Montreal and its port supply chain (O3). Furthermore, the discussion of related topics, including the planning cycle, the risk-analysis system, stakeholder and public participation in improving the adaptation planning, may trigger more discussion and provide workable recommendations for other ports and port supply chain development in adapting to climate change (O4). Meanwhile, planning cycle, the risk-analysis system, stakeholder and public participation are some of the main challenges in improving the adaptation planning for Port of Montreal (answered the second primary research question).

7.2 Theoretical and Practical Contributions

In addition to achieving the four main objectives and solving the primary research questions, this thesis has implications for both theory and practice through examining the aforementioned three theories (path dependence theory, stakeholder management and supply chains risk management in Chapter 2) as well as partially filling the gaps in the research of climate change on ports.

Path dependence emphasizes the significant changes in investment strategy and governance are often attributed to the shift of exogenous events (e.g., the climate change impacts) and role of stakeholders. Most of the ports in the survey and the ports in the two case studies have realized the impacts of climate change occurred in the past and actively adapt to these impacts. Meanwhile, the motivations of an adaptation plan are consistent with the two critical factors in path dependence： the historical climate change event or small changes, and the prediction for climate change in the future. In the case of Manitoba, current adaptation measures are mainly based on the prevention against major risks (e.g., flooding at CentrePort, frozen peatland and permafrost in Hudson Bay Railway). However, several climate change uncertainties (e.g., tornadoes, heavy storms, extreme cold events) are inadequately considered when predict the climate change in the future. This phenomenon might partially explain the reason that both CentrePort and Hudson Bay Railway lacks of a specific adaptation plan for climate change. In Port of Montreal, current adaptation planning corresponds to the path dependency by linking the occurrence of low water level in the past to the prediction of low water level in the future. By doing so, electronic navigation is promoted to the port's stakeholders instead of utilizing traditional dredging which would pose environmental and other issues. Nevertheless, no matter for further initiating or improving the adaptation planning in the two cases, the path dependence theory requires planners to establish a resilient framework to minimized climate change risks and uncertainties as well as concerned with the dynamic interaction among institutional environment, government structure and the landlord port authority.

Supply chain risk management (SCRM), as a major part of supply chain management, requires designing a dynamic supply chain network structure by considering both risks and uncertainties in order to manage the product flow throughout the system to predict, arrange and recover from disruptions (Baghalian, Rezapour, and Farahani, 2013). CentrePort, Hudson Bay Railway and Port of Montreal have concerned with the risks posed by climate change. In particular, Port of Montreal has utilized a comprehensive risk-analysis procedure in port planning. Nevertheless, all the three situations yet considered the potential uncertainties in the entire supply chain. In addition, although it is acknowledged that both of the risks and uncertainties in SCRM are usually related to negative consequences in the most of literature (e.g., Christopher and Lee, 2004, Paulson, 2005, Spekman and Davis, 2004, Wagner and Bode, 2006), the author also investigates the positive impacts posed by climate change (e.g., the longer shipping season in Hudson Bay Railway and Port of Montreal because of global warming). Therefore, how to take the advantage of these opportunities would be another consideration in dealing with the impacts in port supply chain risk management.

Although the path dependence theory has been applied in studies of strategic port planning (Doom et al., 2013), historical conditions cannot serve as the only benchmark for decision-making in the future considering the tendency of more intensive, frequent and unstable climate patterns. SCRM makes up this deficiency by emphasizing the concept port supply chain and quantifying the risks and potential uncertainties in order to design a dynamic supply chain network. Nevertheless, only SCRM may fail to answer the question of how to minimize the risks and uncertainties and maximize the benefits of stakeholders in the entire supply chains, which leads to the utilization of stakeholder management.

Stakeholder management reflects the demand of increasingly intensive competition and integration of multimodal port supply chains (Lam et al., 2013). In the two case studies, the port as its core enterprise has played a key role in combining and coordinating its service providers with customers into an effective system. The multiple stakeholders involve shipping companies, shippers, terminal operators, government and other parties in the two cases. However, It is still a challenge to coordinate all the stakeholders in adapting to the risks and uncertainties. As the impacts posed by climate change become more severe, it requires a comprehensive stakeholder management process where port planners emphasize the role, responsibility and relevance of stakeholders, enhance the public participation in decision making, and consider both risks and uncertainties in port supply chains. The complexity of stakeholder management calls for the collaboration of multiple parties through joint projects and technological innovation. By initiating or improving a specific adaptation plan for climate change in the two cases, it is expected to minimize the conflicts among stakeholders and maximize their common benefits in the future. As noted by Messner et al (forthcoming), the effective application of the stakeholder management would contribute to the reconstruction and improvement of the ports' adaptation-planning paradigm in the future.

The thesis is intended to be a pioneer research on adaptation planning at Canadian ports and fill some of the gaps in the existing research. First, by providing a pioneer survey at ports in Canada with latest and first-hand data, it offers a comprehensive overview of existing adaptation planning among Canadian ports. The survey provides substantial evidence for the existence of a number of the adaptation issues identified in the literature review (e.g., the short planning cycles, inadequate scientific information and design standard and guidelines). Through testing the hypotheses, the thesis highlights the importance of adaptation planning by quantitatively examining the efficiency of adaptation measures (Hypotheses 1 and 2). Meanwhile, the two in-depth case studies develop the discussion about the adaptation planning (e.g., the planning cycle, public participation and risk-analysis system). It is anticipated, therefore, that this thesis will contribute to the future regional studies in relevant topics.

Second, the thesis examines dry ports as important participants in both the survey and case studies and differences between the impacts on seaports and dry ports (as proved in Hypothesis 3). By doing so, it provides an innovative aspect for future research on dry ports and climate change impacts. The results of this also have practical implications for the port industry. The results are expected to share with the most of participants including port, port authorities and relevant associations, which will provide port administrators with a greater appreciation of the risks and uncertainties in port planning, and assist in the consideration of the details of constructing or improving an adaptation plan for climate change. In particular, the participants in the two case studies, the all-round interview and analysis will gain a better appreciation of the risks and uncertainties posed by climate change in decision making and to find their strengths and barriers in future adaptation planning. Based on the results of the survey and interviews, this thesis will contribute to further studies in climate change, port planning, port supply chain management, policy making, risk management and other interdisciplinary areas.

7.3 Limitation and Implications for Future Research

For the survey itself, some limitations still remain. First, respondents mainly came from the members in ACPA and Green Marine, the two leading organizations associated with ports development and environmental issues in Canada, which may limit the survey sample. Other non-member ports, which may be located in remote areas, or may have limited capacity and knowledge in climate change, and which may pose language or communication barriers and other factors, should nevertheless be subject to further research in future projects. On the other hand, one advantage of this sampling is that the 26 respondents on behalf of 21 ports were knowledgeable and authoritative sources, a characteristic that was guaranteed by the two organizations' networks. A second potential limitation is that, since the respondents have more concern about, and interest in, climate change issues than non-respondents, the survey results might have exaggerated climate change impacts or overstated the effectiveness of adaptation panning. Even so, it is believed that the results reflect striking and common problems on ports posed by climate change. Finally, since it is noted earlier, climate change involves a variety of departments in an entity and different stakeholders in a port supply chain, the survey results might be restricted by individual knowledge and perceptions. Understanding such, a broader and deeper investigation among diverse staff within a port and associated stakeholders in, for instance, government, insurance, academia, etc., should be undertaken.

For the two case studies, the limitation lies in the fact that a considerable amount of archival data is lacking, especially the local data in climate change and adaptation at ports. It was for this reason that the interview methodology was adopted, with the objective of acquiring updated and first-hand data for the two case studies (CentrePort, Hudson Bay Rail and Port or Montreal), while the results might be constrained by the limited number of interviewees and interviewees' personal perceptions and experiences so as fail to delivery the all-round realities. Future research on these cases should consider extending the range of interviewees to external stakeholders (e.g., policymakers, environmental officers, managers in rail sectors, etc.). Also, further quantitative and modeling studies might contribute to riching the current qualitative results.

Finally, The regional focus in this thesis also is worth noting. Given that both the survey and case studies only focus on the climate change conditions and adaptations in Canada, the issues at Canadian ports may not reflect the overall situation of global ports or a specific port in other area. Nevertheless, this thesis provides a sound theoretical foundation, creative thinking pattern and practical reference for ports to adapt to climate change impacts in the future. Further research is necessary to draw the experiences from best global practice and look at the key aspects in developing adaptation planning for climate change (e.g., effective risk analysis and systematic risk evaluation, scientific forecasting and transparent information sharing, maximized benefits of stakeholders and broad public participation, wise decision making in planning cycle).

One of the existing challenges in adaptation planning, as many contributors to the book *"Climate Change and Adaptation Planning for Ports"* have pointed out, relies on incentives of the planners: when the length of the concession holders may only be 20 or 30 years, why would a private company decide making investments in the infrastructure that would benefit the future holder of the concession? (Ng et al., forthcoming). In particular, in what portions does a corporate planner distribute the investment between the short-term and long-term under the limited financial budget? Both of the above challenges require more precise data collection and cost-benefit analysis at the early designing stage of adaptation planning in the future. Simultaneously, even if the sufficient investment could alleviate the damage caused by climate change, the government and relevant investor are still facing the risks of "overinvestment" when if there will be no disaster occurrence. Further investment, as Xiao et al (2015) indicated, investment for disaster prevention should be based on an integrated economic model involving the factors of optimal timing, uncertainty of disaster occurrence, investment return, information accumulation as well as the benefit distribution of all the stakeholders.

The author also recognizes that government and related sectors have been playing pivotal roles in assisting ports to deal with risks and uncertainties posed by climate change as well as developing adaptation plans. We may unfortunately find that the lack of a specific adaptation plan for an individual port is mainly attributed to the deficiencies of top-down policies or guidelines in adapting to the climate change. Overall climate change or regional environmental policies may not easy to customize the specific climate change issues at an individual port, and ports may hard to apply the high level policy into guiding ports' operation and adaptation planning. This phenomenon exists among the ports that have no specific adaptation plan for climate change, no matter in the national survey (8% respondents have no specific adaptation document) or in the case of Manitoba (CentrePort and Hudson Bay railway). Meanwhile, even for the ports and the area where the policies exist (e.g., Port of Montreal), how to guarantee the power of execution and sufficient investment to put into practice the implementation or improvement of adaptation planning is another issue that deserves thinking in the future.

Last but not least, the latest global research in climate change and adaptation planning is coherent with the investigations of this thesis that some ports have initiated the adaptation process through analyzing the challenges and opportunities posed by climate change, while only few have implemented adaptation planning specifically for climate change. To change the existing conventional thinking patterns in adaptation planning, it calls for a standardized adaptation process (e.g., from “defining the problem, identifying and selecting strategies, to implementing strategies, monitoring and evaluating, and sharing lessons learn”(Becker, forthcoming, pp.267)) supported by strong stakeholder management. An innovative and referable example to establish adaptation-planning paradigm has been utilized in Port of San Diego, USA (PSD), by reconstructing outcome-oriented reverse planning steps in the Theory of Change (TOC)(Messner et al., forthcoming). By doing so, it requires senior policymakers, industrial practitioners and researchers to understand the dynamics between climate change, adaptation planning of ports and transportation infrastructures and improve current adaptation planning with comprehensive guidance, innovative assessment approaches and global experiences.

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Appendix A

QUESTIONNAIRE

INFORM CONSENT

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 is the name of your port/terminal?

____

EXISTING CLIMATE CHANGE RISKS & UNCERTAINTIES

How, if at all, has climate change impacted your port/terminal in the past 10 years?

Description of Variables

Frequency:

1.Very frequent--Happened more than once per year

2.Frequent--Happened on average once per year

3.Sometimes--Happened more than once, but fewer than 10 times in the past decade

4.Seldom--Happened once in the past decade

5.Never--Did not happen in the past decade

Severity of consequences:

1.Catastrophic--Very severe economic loss and/or disruption on the facilities/systems/services *requiring a very long period and very high cost of recover*

2.Critical--Severe economic loss and/or disruption on the facilities/systems/services requiring a long period and high cost of recovery

3.Major--Significant economic loss and/or disruption on the facilities/systems/services requiring certain length of time and cost of recovery

4.Minor--Some economic loss and/or disruption on the facilities/systems/services requiring some time and cost of recovery

5.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

Please mark each two item in 1-5 in the following questions 4 and 5.

4. Sea Level Rise due to climate change in the past 10 years

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

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

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

6. What types of RISKS do you think posed by climate change at your port/terminal in the past 10 years? (Please choose ALL items which impacted your port/terminal; if not at all, please do not choose)

- □ Sea Level Rise
- □ High Winds
- □ Storm Surges
- □ Extreme Weather
- □ Flooding
- □ Precipitation Change
- □ Landslide
- □ Muskeg
- □ Permafrost
- □ Other (please specify) ________________________________

7. What types of UNCERTAINTIES do you think will be posed by the climate change at your port/terminal in the future?(Please choose ALL items which might impact your port/terminal; if not at all, please do not choose)

- □ Sea Level Rise
- □ High Winds

- ◻ Storm Surges
- ◻ Extreme Weather
- ◻ Flooding
- ◻ Precipitation Change
- ◻ Landslide
- ◻ Muskeg
- ◻ Permafrost
- ◻ Other (please specify) ________________________________

8. Please list the top three impacts that climate change might have on your port's operations.

(1)_________________________________

(2)_________________________________

(3)_________________________________

9. If your port/terminal has been impacted by climate change in the past 10 years, please write down the event (e.g., the name(s), happened year(s), main damages).

____

____

10. If you answered yes to question 9, what were the approximate financial costs of these events (Can dollars)?

____

____

ADAPTING TO THE RISKS

11. If you answered yes to question 9, what were the other consequences of these events do you think at your port/terminal in the years?

____

____

12. Has your port implemented an adaptation plan for climate change?

□ Yes, we have implemented an adaptation plan

□ No, we have not implemented but we will consider an adaptation plan in the future

□ Neither has we implemented nor will consider an adaptation plan in the future

PLANNING AND MEASURES FOR CLIMATE CHANGE

13. How does your port address the climate change impacts on port operations, (e.g., sea level rise, storm surges, flooding, etc.)? (Please choose ALL items that CURRENTLY apply to your port/terminal)

□ Climate change specifically addressed in your insurance coverage

□ Climate change written into your strategic plan

□ Part of the design guidelines or standards that you use

□ Addressed through a specific climate change planning document

□ Addressed and funded as a line item in your budget

□ Not addressed currently

□ I am not sure

□ Other (please specify) ________________________________

14. What protective measures do your port currently have in coping with climate change? (Please choose ALL items that have CURRENTLY considered in your port/terminal planning; if not at all, please do not choose)

□ Sea Wall

□ Flooding Insurance

□ Lock System

- ◻ Drainage Pumps
- ◻ Storm Insurance
- ◻ Storm Barrier
- ◻ Storm Response Plans
- ◻ Breakwater
- ◻ Protective Dike
- ◻ Port lands elevated above historical height
- ◻ Future plans to replace/upgrade existing structures
- ◻ Other (please specify) ________________________________

15. Which aspects have been considered in addressing climate change impacts? (Please choose ALL items which have CURRENTLY considered in your port/terminal planning)

- ◻ Potential effects on facility operations
- ◻ Demand of transport infra-and superstructures (e.g., cranes and warehouses) and utilities
- ◻ Demand of new equipment and facility maintenance
- ◻ Potential impacts on maritime accesses (e.g., shipping)
- ◻ Potential impacts on overland and other accesses (highway, rail, air)
- ◻ Effect on logistics
- ◻ Air pollution/air quality
- ◻ Revision of construction design standards
- ◻ Potential shifts in source or market locations and population centers (customer base/location)
- ◻ Potential impacts on surrounding community and environment
- ◻ Other (please specify) ________________________________

16. What is your port's planning horizon in addressing the impacts of climate change?

- ◻ Less than 5 years
- ◻ 5-10 years
- ◻ 10-15 years

- ☐ 15-20 years
- ☐ 20-25 years
- ☐ 25-50 years
- ☐ more than 50 years
- ☐ Other (please specify) ______________________________

ADAPTATION STRATEGIES IN THE FUTURE

Which climate change risks and uncertainties 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:*

1. Very Long--More than 20 years

2. Long--Approximately 15 years

3. Medium--Approximately 10 years

4. Short--Approximately 5 years

5. Very short--Less than 1 year

Severity of consequences:

1.Catastrophic--Very severe economic loss and/or disruption on the facilities/systems/services requiring a very long period and very high cost of recovery

2.Critical--Severe economic loss and/or disruption on the facilities/systems/services requiring a long period and high cost of recovery

3.Major--Significant economic loss and/or disruption on the facilities/systems/services requiring certain length of time and cost of recovery

4.Minor--Some economic loss and/or disruption on the facilities/systems/services requiring some time and cost of recovery

5.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:*

1.<u>Very High</u>--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
2.<u>High</u>--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
3.<u>Average</u>--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
4.<u>Low</u>--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
5.<u>Very low</u>--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

Please mark each THREE item in 1-5 in the following question 17 and 18.

17. 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) 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 flooding	______	______	______

18. Increased Intensity and/or frequency of high wind and/or storms

	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 ______ ______ ______

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:*

1.<u>Very High</u>--involves a very high financial cost so as to comprehensively address the stated potential effect

2.<u>High</u>--involves a high financial cost so as to comprehensively address the stated potential effect

3.<u>Average</u>--involves a significant financial cost so as to comprehensively address the stated potential effect

4.<u>Low</u>--involves a financial cost (though not that significant) so as to comprehensively address the stated potential effect

5.<u>Very low</u>--involves a minimal financial cost so as to comprehensively address the stated potential effect

***Timeframe** for when you expect to first see this impact:*

1.<u>Very Long</u>--More than 20 years

2.<u>Long</u>--Approximately 15 years

3.<u>Medium</u>--Approximately 10 years

4.<u>Short</u>--Approximately 5 years

5.Very short--Less than 1 year

Severity of consequences:

1.Catastrophic--Very severe economic loss and/or disruption on the facilities/systems/services requiring a very long period and very high cost of recovery

2.Critical--Severe economic loss and/or disruption on the facilities/systems/services requiring a long period and high cost of recovery

3.Major--Significant economic loss and/or disruption on the facilities/systems/services requiring certain length of time and cost of recovery

4.Minor--Some economic loss and/or disruption on the facilities/systems/services requiring some time and cost of recovery

5.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:*

1.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

2.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

3.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

4.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

5.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

Please mark each FOUR item in 1-5 in the following question 19 and 20.

19. Sea Level Rise

	Financial Cost of Adaptation	Timeframe	Severity	Likelihood
(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) _______ _______ ______ _______

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

	Financial Cost of Adaptation	Timeframe	Severity	Likelihood
(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) Downtime in port/terminal operation due to the increase of high winds and storms (Adaptation Measure: Improve management to prevent effects)	_______	_______	_____	_______
(f) All the risks and impacts above (Adaptation Measure: Move facilities away from existing locations which are vulnerable to climate change risks and impacts)	_______	_______	_____	_______

ADAPTING TO THE RISKS

ADAPTATION PLAN & STRATEGIES

In question 12, (has your port implemented an adaptation plan for climate change?), if you answered "Neither have we implemented nor will consider an adaptation plan in the future", please do not answer the following questions (21-25).

21. Who are (will your port already has an adaptation plan) or/ will be the PARTICIPANTS in an ADAPTATION PLAN? (Please choose ALL items which indicates whom you think the participants are)

□ Shipping Lines

□ Freight

□ Forwarders

□ Dock Workers

□ Labor Unions

□ Interest Groups

□ NGOs

□ Consultants

□ Other (please specify) ________________________________

22. What is/ will be the time horizon for the climate ADAPTATION PLAN?

□ Less than 5 years

□ 5-10 years

□ 10-15 years

□ 15-20 years

□ 20-25 years

□ 25-50 years

□ more than 50 years

□ Other (please specify) ________________________________

23. When developing the adaptation strategies in your port's adaptation plan, did /will you make REFERENCES to your port's established planning norms, practices and

experiences? (please choose ALL items which indicate the references you think should make)

□ Port Master Plan

□ Regional Transportation Plan

□ Regional Environmental Plan

□ The Experiences of Other Ports' Adaptation Plan

□ Other Port-related Plans

□ Other (please specify) ________________________________

24. Please RANK the following items which you conside are important in port's adaptation plan to address climate change threats to your port and its surrounding regions? (please choose and rank ALL items) (e.g., 1,2,3...,6; please choose each rank only once)

( ) Study of Existing Condition

( ) Identification of Current Vulnerabilities

( ) Risk Analysis

( ) Prioritization

( ) Development of Strategies for Implementation

( ) Other (please specify) ________________________________

25. Please RANK the following items which you consider are important in your port's adaptation strategies so as to ensure that such strategies can be justified as 'SUCCESSFUL'? (please choose and rank ALL items which might impact the success of adaptation strategies) (e.g., 1,2,3...,7; please choose each rank only once)

( ) Budgetary constraints

( ) Benefits of stakeholders

( ) Port Master Plan

( ) Other Port-related Plans

( ) Public opinion

( ) Public Policy

( ) Other (please specify) ________________________________

OTHER COMMENTS

26. Additional Comments:

____

27.What is your current position at your port? (Optional)

- ◻ CEO or Port Director
- ◻ Engineer
- ◻ Planner
- ◻ Public Relations Director
- ◻ Development Director
- ◻ Safety or Security Director
- ◻ Other (please specify) ______________________________________

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

Appendix B

QUESTIONS FOR INTERVIEW

Part A. Identifying the vulnerabilities of ports posed by climate change

A1. There is a variety of vulnerabilities that climate change posed or probably to your port and stakeholders (e.g., sea level rise (SLR), hurricane). What kind of risks are your main concerns in your port's planning?

A2. Have you had corresponding adaptation plans to cope with above risks? If so, could you introduce this plan (or these plans) in terms of the time horizon, the participants and the effect of these plans etc? If not, why are you planning to develop one? And why? What are the main factors restrained the implementation of adaptation plan?

A3. Are there any other potential threats or uncertainties on your port due to the climate change besides SLR and hurricane? For your port, will you consider these uncertainties at all? Will you take adaptation plans to minimize them in the future? If so, what type of resources will you use to identify, forecast and assess these uncertainties? If not, why do you think it is unnecessary and what would be the barriers in an adaptation plan (e.g., the policy, financial budget)?

A4. In coping with these risks and uncertainties posed by climate change, there are two main methods: adaptation strategies and mitigation strategies. What's the main strategy in your port's current planning? Do you think that it is different with the plans of ten years (or a few years) ago? And would it be changed in the future (a long term plan)?

A5. Currently, there are more attention placed on mitigation strategies than adaptation strategies. What are the possible reasons do you think? And do you think an adaptation plan is urgent from the perspective of global level and local level? Why do (or don't) you think so?

Part B. Risk assessment and planning priority

B1. As a port already had (or will have) an adaptation plan, what are your main priorities, the most pressing issues should be addressed in a short term? How did you (or will you) define and assess these priorities (e.g., by collecting the scientific data, evaluating the opinions of

stakeholders or participants)? Which channel do you think should be put to the priority?
B2. Similarly, what kind of issues do you think are lower priority/risk, which can be coped with in a longer term? Why do you think so? And when do you think that they should be consider and why?
B3. Do you have an risk analysis systems in assessing vulnerabilities posed by climate change? If so, could you introduce the application of them? (e.g., what are evaluation indicators? Did they achieve your expected effects? Who participant in the assessment?). In addition, how were they (or will they) contribute to the adaptation plan?
B4. In an adaptation plan, which principles do you think are fundamental, namely could not be effected by external parties opinion? Are they consistent with surrounding environment at all (e.g., the public policy, Port Master Plan, benefits of stakeholders)? If not, why not? And how could you minimize the inconsistences?

Part C. Recognizing the characteristics and differences of ports' condition

C1. As a relatively new challenge, there are lacking exact planning patterns in adaptation strategies. Thus, for your port planning, did you (or will you) borrow the advanced experiences from other ports? What are your main accesses to get these information (e.g., journal articles, workshops, websites, professional consultants)? Also, are there any local references (e.g., local research and consulting reports) that you can use to develop your port's adaptation plan? If so, what are these local references? Are they accessible and applicable to your port's reality?
C2. Following the above question, do you think there is different research in international, national and regional level on adaptation strategies? If so, what are the differences? Which parts' value did you (or will you) place more importance?
C3. What are strengths and (or) weaknesses of your port in adaptation plans? How did you (or could you) localize these higher level knowledge into your port's practice?

Part D. The preparation, environment and stakeholders involving an adaptation plan

ADAPTING TO THE RISKS

C1. What attributes do you think facilitate an adaptation plan (e.g., the requirement of government policy, the demand of port's operation)? Do you think that adaptation plan is a practical action or just engaging in idle theorizing? Why do you think so? What type of supports would be given to improve or change this situation?
C2. Who did (or will) involve in the adaptation plan (e.g., shipping lines, freight forwarders, dock workers, labor unions, interest groups, NGOs, consultants, etc.)? Are there trade-offs among different parties? What roles did (or will) they play (e.g., consulting, drafting, decision-making)?
C3. Which parties' opinion did you (or will you) put into the top list? How did you (or will you) balance the various benefits in decision-making?
C4. In conducting an adaptation plan, what kind of supports did you (will you) get from port's high level, institutions, national and international society? And anything else do you think should be added?

Part E. Implementing an adaptation plan and developing adaptation strategies

E1. What is the time horizon do you think for your port's adaptation strategies (e.g., 5, 10, 20, 50, or more)? Are there any specific reasons or reference to design this time-span (e.g., make a reference from your Port Master Plan, the experience of other port, financial or infrastructural conditions)?
E2. In what conditions do you think adaptation strategies are successful? What factors will effect the achievement of adaptation strategies? Could you list them out and provide a general ranking?
E3. In your opinion, to what extent do "financial constraint", "Port Master Plan", "public opinion" and other factors affect the development of adaptation strategies in your port's adaptation plan? Why do you think so? could you give me some examples?
E4. Do you make references to your port's established planning norms, practices and experiences (e.g., experiences from other ports, your Port Master Plan, regional transportation and environmental plans)? If so, how will they impact the adaptation strategies of your port?

E5. Up to now, there are rare rules, regulations and guidelines for developing an adaptation plan. How do you think this situation? What could be done to improve it? In addition, there is a relative shortage of public participants, what's the situation of your port's adaptation plan? How did you (or will you) ensure a relatively high participant rate and guarantee that your adaptation strategies are acceptable to the public of your port and your city?

BASIC INFORMATION OF INTERVIEWEES

Interviewee	Position	Organization	Interview Date
Interviewee 1	Senior	CentrePort Canada	July 15th 2014
Interviewee 2	Middle	Manitoba Infrastructure and Transportation	July 24th 2014
Interviewee 3	Middle	University of Winnipeg	July 31st 2014
Interviewee 4	Senior	Bison Transport	August 1st 2014
Interviewee 5	Middle	Manitoba Trucking Association	August 14th 2014
Interviewee 6	Middle	Churchill Gateway Development Corporation	August 14th 2014
Interviewee 7	Middle	York University	August 11th 2014
Interviewee 8	Middle	Green Marine Management Corporation	December 16th 2014
Interviewee 9	Middle	Port of Montreal	January 12th 2015
Interviewee 10	Middle	University of Montreal	January 12th 2015
Interviewee 11	Middle	Port of Montreal	January 13th 2015
Interviewee 12	Senior	Association of Canadian Port Authorities	March 4th 2015

Remarks: " Senior" means Vice President, President etc.

" Middle" means Executive Director, Environment Director, Research Director, Professor, Associate Professor, etc.

Appendix C

TABLES

Table 1-T-Test: the means of every item in SLR and storms with and without measures

Group Statistics

	Protective measures	N	Mean	Std. Deviation	Std. Error Mean
SLR frequency a	without measures	7	4.57	.787	.297
	with measures	17	4.59	.795	.193
SLR frequency b	without measures	7	4.86	.378	.143
	with measures	17	4.71	.686	.166
SLR frequency c	without measures	7	4.29	.756	.286
	with measures	17	4.53	.874	.212
SLR frequency d	without measures	7	4.00	.816	.309
	with measures	17	4.06	1.345	.326
SLR frequency e	without measures	7	4.43	.976	.369
	with measures	17	4.82	.728	.176
SLR severity a	without measures	5	4.80	1.095	.490
	with measures	10	4.90	.738	.233
SLR severity b	without measures	5	5.00	.707	.316
	with measures	11	5.09	.701	.211
SLR severity c	without measures	6	4.50	.837	.342
	with measures	11	4.64	.924	.279
SLR severity d	without measures	7	4.86	.690	.261
	with measures	12	4.50	1.000	.289
SLR severity e	without measures	6	4.33	1.211	.494
	with measures	10	5.10	.876	.277
Storms frequency a	without measures	8	4.25	.463	.164
	with measures	18	4.44	.856	.202
Storms frequency b	without measures	8	4.00	1.195	.423
	with measures	18	4.44	.922	.217
Storms frequency c	without measures	8	3.38	.916	.324
	with measures	17	4.12	1.054	.256
Storms frequency d	without measures	8	4.00	.926	.327
	with measures	18	4.72	1.018	.240
Storms severity a	without measures	7	4.29	.488	.184
	with measures	12	4.67	.985	.284
Storms severity b	without measures	5	4.20	1.095	.490
	with measures	12	4.67	.778	.225
Storms severity c	without measures	8	4.00	1.414	.500

	with measures	13	4.46	.776	.215
Storms severity d	without measures	7	4.29	.951	.360
	with measures	12	4.17	1.899	.548

Table 2-T-Test: the significance of every item in SLR and storms with and without measures

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
SLR frequency a	Equal variances assumed	.040	.844	-.047	22	.963	-.017	.356	-.755	.722
	Equal variances not assumed			-.047	11.356	.963	-.017	.354	-.794	.760
SLR frequency b	Equal variances assumed	2.881	.104	.546	22	.591	.151	.277	-.424	.726
	Equal variances not assumed			.690	19.714	.498	.151	.219	-.307	.609
SLR frequency c	Equal variances assumed	.351	.559	-.643	22	.527	-.244	.379	-1.030	.542
	Equal variances not assumed			-.685	12.959	.505	-.244	.356	-1.013	.525
SLR frequency d	Equal variances assumed	1.504	.233	-.107	22	.916	-.059	.550	-1.198	1.081
	Equal variances not assumed			-.131	18.320	.897	-.059	.449	-1.001	.883
SLR frequency e	Equal variances assumed	2.038	.167	-1.095	22	.285	-.395	.361	-1.143	.353
	Equal variances not assumed			-.966	8.886	.360	-.395	.409	-1.322	.532
SLR severity a	Equal variances assumed	.335	.573	-.211	13	.836	-.100	.473	-1.122	.922
	Equal variances not assumed			-.184	5.886	.860	-.100	.543	-1.434	1.234

SLR severity b	Equal variances assumed	.130	.724	-.240	14	.814	-.091	.379	-.904	.722
	Equal variances not assumed			-.239	7.750	.817	-.091	.380	-.973	.791
SLR severity c	Equal variances assumed	.169	.687	-.300	15	.768	-.136	.455	-1.106	.833
	Equal variances not assumed			-.309	11.358	.763	-.136	.441	-1.103	.830
SLR severity d	Equal variances assumed	2.307	.147	.832	17	.417	.357	.429	-.549	1.263
	Equal variances not assumed			.918	16.334	.372	.357	.389	-.466	1.181
SLR severity e	Equal variances assumed	1.350	.265	-1.472	14	.163	-.767	.521	-1.883	.350
	Equal variances not assumed			-1.353	8.181	.212	-.767	.567	-2.068	.535
Storms frequency a	Equal variances assumed	5.078	.034	-.600	24	.554	-.194	.324	-.863	.474
	Equal variances not assumed			-.749	22.775	.462	-.194	.260	-.732	.343
Storms frequency b	Equal variances assumed	1.422	.245	-1.036	24	.310	-.444	.429	-1.330	.441
	Equal variances not assumed			-.935	10.877	.370	-.444	.475	-1.492	.603
Storms frequency c	Equal variances assumed	.267	.610	-1.709	23	.101	-.743	.435	-1.642	.157
	Equal variances not assumed			-1.800	15.757	.091	-.743	.413	-1.618	.133
Storms frequency d	Equal variances assumed	.078	.782	-1.714	24	.099	-.722	.421	-1.592	.148
	Equal variances not assumed			-1.780	14.784	.096	-.722	.406	-1.588	.144
Storms severity a	Equal variances assumed	5.234	.035	-.950	17	.356	-.381	.401	-1.227	.465
	Equal variances not assumed			-1.124	16.764	.277	-.381	.339	-1.097	.335
Storms severity b	Equal variances assumed	.143	.711	-1.003	15	.332	-.467	.465	-1.459	.525
	Equal variances not assumed			-.866	5.768	.421	-.467	.539	-1.798	.865
Storms severity c	Equal variances assumed	.082	.777	-.972	19	.343	-.462	.475	-1.456	.533

	Equal variances not assumed			-.848	9.643	.417	-.462	.544	-1.681	.758
Storms severity d	Equal variances assumed	1.507	.236	.154	17	.880	.119	.775	-1.515	1.753
	Equal variances not assumed			.182	16.800	.858	.119	.656	-1.265	1.503

Table 3- T-Test: The means of averaged SLR and storms with or without measures

Group Statistics

	Protective measures	N	Mean	Std. Deviation	Std. Error Mean
slr_ave_fre	without measures	7	4.4286	.35456	.13401
	with measures	17	4.5412	.68105	.16518
slr_ave_sev	without measures	7	4.7143	.95119	.35952
	with measures	13	4.8077	.75107	.20831
sto_ave_fre	without measures	8	3.9375	.72887	.25769
	with measures	18	4.4722	.79469	.18731
sto_ave_sev	without measures	8	4.2500	.88641	.31339
	with measures	16	4.3125	1.30224	.32556

Table 4- T-Test: The significance of averaged SLR and storms with or without measures

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	Df
slr_ave_fre	Equal variances assumed	3.244	.085	-.411	22
	Equal variances not assumed			-.529	20.412
slr_ave_sev	Equal variances assumed	.259	.617	-.242	18
	Equal variances not assumed			-.225	10.134
sto_ave_fre	Equal variances assumed	.204	.655	-1.622	24
	Equal variances not assumed			-1.678	14.665
sto_ave_sev	Equal variances assumed	.196	.662	-.122	22
	Equal variances not assumed			-.138	19.605

Independent Samples Test

	t-test for Equality of Means		
	Sig. (2-tailed)	Mean Difference	Std. Error

				Difference
slr_ave_fre	Equal variances assumed	.685	-.11261	.27376
	Equal variances not assumed	.602	-.11261	.21270
slr_ave_sev	Equal variances assumed	.811	-.09341	.38592
	Equal variances not assumed	.827	-.09341	.41550
sto_ave_fre	Equal variances assumed	.118	-.53472	.32977
	Equal variances not assumed	.114	-.53472	.31858
sto_ave_sev	Equal variances assumed	.904	-.06250	.51349
	Equal variances not assumed	.891	-.06250	.45189

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
slr_ave_fre	Equal variances assumed	-.68036	.45515
	Equal variances not assumed	-.55572	.33051
slr_ave_sev	Equal variances assumed	-.90420	.71738
	Equal variances not assumed	-1.01755	.83074
sto_ave_fre	Equal variances assumed	-1.21533	.14588
	Equal variances not assumed	-1.21511	.14566
sto_ave_sev	Equal variances assumed	-1.12741	1.00241
	Equal variances not assumed	-1.00634	.88134

Table 5-T-test: the means of risks and uncertainties with and without measures

Group Statistics

	Protective measures	N	Mean	Std. Deviation	Std. Error Mean
Risks	without measures	8	1.25	.886	.313
	with measures	18	2.94	1.589	.375
Uncertainties	without measures	8	2.00	1.690	.598
	with measures	18	3.44	1.653	.390

Table 6-T-test: the significance of risks and uncertainties with and without measures

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	Df
Risks	Equal variances assumed	1.349	.257	-2.807	24
	Equal variances not assumed			-3.469	22.435
Uncertainties	Equal variances assumed	.225	.640	-2.043	24
	Equal variances not assumed			-2.025	13.230

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Risks	Equal variances assumed	.010	-1.694	.604
	Equal variances not assumed	.002	-1.694	.488
Uncertainties	Equal variances assumed	.052	-1.444	.707
	Equal variances not assumed	.064	-1.444	.713

Independent Samples Test

		t-test for Equality of Means 95% Confidence Interval of the Difference	
		Lower	Upper
Risks	Equal variances assumed	-2.940	-.448
	Equal variances not assumed	-2.706	-.683
Uncertainties	Equal variances assumed	-2.904	.015
	Equal variances not assumed	-2.983	.094

Table 7- Regression: the number of risks and uncertainties with measures on ports

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.790[a]	.624	.591	1.176

a. Predictors: (Constant), Uncertainties, Risks

a. Dependent Variable: Protective measures 2

b. Predictors: (Constant), Uncertainties, Risks

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	.204	.462		.442	.662
	Risks	1.657	.369	1.445	4.495	.000
	Uncertainties	-.817	.335	-.784	-2.440	.023

a. Dependent Variable: Protective measures 2

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	52.784	2	26.392	19.070	.000[b]
	Residual	31.831	23	1.384		
	Total	84.615	25			

Table 8- Regression: the number risks and uncertainties with measures on seaports

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.783[a]	.613	.565	1.306

a. Predictors: (Constant), Sea_Uncert, Sea_Risks

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	43.238	2	21.619	12.676	.001[b]
	Residual	27.288	16	1.706		
	Total	70.526	18			

a. Dependent Variable: Seap_Pro_Mea_2
b. Predictors: (Constant), Sea_Uncert, Sea_Risks

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.338	.539		.627	.540
	Sea_Risks	1.534	.446	1.393	3.440	.003

Sea_Uncert	-.708	.401	-.714	-1.764	.097

a. Dependent Variable: Seap_Pro_Mea_2

Table 9- Regression: the number risks and uncertainties with measures on dry ports

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.949[a]	.900	.851	.585

a. Predictors: (Constant), Dryp_Uncert, Dryp_Risks

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	12.348	2	6.174	18.070	.010[b]
	Residual	1.367	4	.342		
	Total	13.714	6			

a. Dependent Variable: Dryp_Pro_Mea_2
b. Predictors: (Constant), Dryp_Uncert, Dryp_Risks

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.633	.854		-.742	.499
	Dryp_Risks	2.467	.465	1.552	5.303	.006
	Dryp_Uncert	-1.367	.465	-.860	-2.938	.042

a. Dependent Variable: Dryp_Pro_Mea_2

b. Based on 4913 samples

Table 10-T-Test: the means of every item in SLR and storms on seaport and dry ports

Group Statistics

	Type	N	Mean	Std. Deviation	Std. Error Mean
SLR frequency a	seaport	17	4.53	.800	.194
	dryport	7	4.71	.756	.286
SLR frequency b	seaport	17	4.82	.529	.128
	dryport	7	4.57	.787	.297
SLR frequency c	seaport	17	4.35	.931	.226
	dryport	7	4.71	.488	.184

SLR frequency d	seaport	17	3.88	1.317	.319
	dryport	7	4.43	.787	.297
SLR frequency e	seaport	17	4.76	.831	.202
	dryport	7	4.57	.787	.297
SLR severity a	seaport	10	4.60	.699	.221
	dryport	5	5.40	.894	.400
SLR severity b	seaport	10	4.90	.568	.180
	dryport	6	5.33	.816	.333
SLR severity c	seaport	12	4.33	.778	.225
	dryport	5	5.20	.837	.374
SLR severity d	seaport	13	4.46	.877	.243
	dryport	6	5.00	.894	.365
SLR severity e	seaport	11	4.64	1.027	.310
	dryport	5	5.20	1.095	.490
Storms frequency a	seaport	19	4.26	.806	.185
	dryport	7	4.71	.488	.184
Storms frequency b	seaport	19	4.16	1.119	.257
	dryport	7	4.71	.488	.184
Storms frequency c	seaport	18	3.72	1.127	.266
	dryport	7	4.29	.756	.286
Storms frequency d	seaport	19	4.42	1.071	.246
	dryport	7	4.71	.951	.360
Storms severity a	seaport	14	4.36	.745	.199
	dryport	5	5.00	1.000	.447
Storms severity b	seaport	12	4.33	.778	.225

Table 11- the significance of every item in SLR and storms on seaport and dry ports

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper

SLR frequency a	Equal variances assumed	.831	.372	-.522	22	.607	-.185	.354	-.919	.549
	Equal variances not assumed			-.535	11.861	.602	-.185	.345	-.938	.569
SLR frequency b	Equal variances assumed	1.831	.190	.920	22	.367	.252	.274	-.316	.820
	Equal variances not assumed			.778	8.330	.458	.252	.324	-.490	.994
SLR frequency c	Equal variances assumed	5.326	.031	-.964	22	.345	-.361	.375	-1.138	.416
	Equal variances not assumed			-1.239	20.341	.229	-.361	.292	-.969	.246
SLR frequency d	Equal variances assumed	1.043	.318	-1.017	22	.320	-.546	.537	-1.660	.568
	Equal variances not assumed			-1.251	18.568	.226	-.546	.436	-1.461	.369
SLR frequency e	Equal variances assumed	.005	.943	.525	22	.605	.193	.368	-.570	.956
	Equal variances not assumed			.538	11.846	.601	.193	.359	-.591	.977
SLR severity a	Equal variances assumed	.593	.455	-1.910	13	.078	-.800	.419	-1.705	.105
	Equal variances not assumed			-1.750	6.546	.126	-.800	.457	-1.896	.296
SLR severity b	Equal variances assumed	2.174	.162	-1.258	14	.229	-.433	.345	-1.172	.306
	Equal variances not assumed			-1.145	7.949	.286	-.433	.379	-1.307	.441
SLR severity c	Equal variances assumed	.018	.895	-2.050	15	.058	-.867	.423	-1.768	.035
	Equal variances not assumed			-1.986	7.072	.087	-.867	.436	-1.897	.163
SLR severity d	Equal variances assumed	.088	.770	-1.237	17	.233	-.538	.435	-1.457	.380
	Equal variances not assumed			-1.227	9.632	.249	-.538	.439	-1.521	.444
SLR severity e	Equal variances assumed	.266	.614	-.998	14	.335	-.564	.565	-1.775	.647
	Equal variances not assumed			-.973	7.364	.362	-.564	.580	-1.920	.793
Storms frequency a	Equal variances assumed	1.785	.194	-1.380	24	.180	-.451	.327	-1.126	.223

	Equal variances not assumed			-1.728	18.040	.101	-.451	.261	-1.000	.097
Storms frequency b	Equal variances assumed	4.122	.054	-1.260	24	.220	-.556	.442	-1.468	.355
	Equal variances not assumed			-1.761	22.995	.092	-.556	.316	-1.210	.097
Storms frequency c	Equal variances assumed	2.011	.170	-1.212	23	.238	-.563	.465	-1.525	.398
	Equal variances not assumed			-1.444	16.511	.167	-.563	.390	-1.389	.262
Storms frequency d	Equal variances assumed	1.022	.322	-.636	24	.531	-.293	.461	-1.244	.658
	Equal variances not assumed			-.673	12.034	.513	-.293	.435	-1.242	.655
Storms severity a	Equal variances assumed	.835	.374	-1.519	17	.147	-.643	.423	-1.536	.250
	Equal variances not assumed			-1.313	5.674	.240	-.643	.490	-1.858	.572
Storms severity b	Equal variances assumed	.441	.517	-1.485	15	.158	-.667	.449	-1.623	.290
	Equal variances not assumed			-1.332	6.133	.230	-.667	.501	-1.885	.552
Storms severity c	Equal variances assumed	.225	.641	-1.859	19	.079	-.857	.461	-1.822	.108
	Equal variances not assumed			-1.953	13.815	.071	-.857	.439	-1.800	.085
Storms severity d	Equal variances assumed	.053	.821	-1.712	17	.105	-1.343	.784	-2.997	.312
	Equal variances not assumed			-2.059	10.612	.065	-1.343	.652	-2.785	.099

Table 12-T-Test: the means of averaged SLR and storms on seaports and dry ports

Group Statistics

	Type	N	Mean	Std. Deviation	Std. Error Mean
slr_ave_fre	seaport	17	4.4706	.64785	.15713
	dryport	7	4.6000	.48990	.18516
slr_ave_sev	seaport	13	4.5000	.70711	.19612
	dryport	7	5.2857	.75593	.28571
sto_ave_fre	seaport	19	4.1316	.84725	.19437
	dryport	7	4.7857	.39340	.14869
sto_ave_sev	seaport	17	4.0000	1.17260	.28440

	dryport	7	5.0000	.81650	.30861

Table 13-T-Test: the significance of averaged SLR and storms on seaports and dry ports

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	Df
slr_ave_fre	Equal variances assumed	1.292	.268	-.473	22
	Equal variances not assumed			-.533	14.862
slr_ave_sev	Equal variances assumed	.000	.984	-2.316	18
	Equal variances not assumed			-2.267	11.688
sto_ave_fre	Equal variances assumed	4.491	.045	-1.948	24
	Equal variances not assumed			-2.673	22.310
sto_ave_sev	Equal variances assumed	.038	.848	-2.048	22
	Equal variances not assumed			-2.383	16.150

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
slr_ave_fre	Equal variances assumed	.641	-.12941	.27343
	Equal variances not assumed	.602	-.12941	.24285
slr_ave_sev	Equal variances assumed	.033	-.78571	.33930
	Equal variances not assumed	.043	-.78571	.34655
sto_ave_fre	Equal variances assumed	.063	-.65414	.33587
	Equal variances not assumed	.014	-.65414	.24472
sto_ave_sev	Equal variances assumed	.053	-1.00000	.48821
	Equal variances not assumed	.030	-1.00000	.41967

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
slr_ave_fre	Equal variances assumed	-.69646	.43764
	Equal variances not assumed	-.64744	.38862
slr_ave_sev	Equal variances assumed	-1.49855	-.07288
	Equal variances not assumed	-1.54301	-.02842

sto_ave_fre	Equal variances assumed	-1.34734	.03907
	Equal variances not assumed	-1.16125	-.14702
sto_ave_sev	Equal variances assumed	-2.01249	.01249
	Equal variances not assumed	-1.88898	-.11102

Table 14- T-Test: the means of risks and uncertainties on seaports and dry ports

Group Statistics

	Type	N	Mean	Std. Deviation	Std. Error Mean
Risks	seaport	19	2.32	1.797	.412
	dryport	7	2.71	.951	.360
Uncertainties	seaport	19	2.89	1.997	.458
	dryport	7	3.29	.951	.360

Table 15- T-Test: the significance of risks and uncertainties on seaports and dry ports

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	Df
Risks	Equal variances assumed	3.345	.080	-.554	24
	Equal variances not assumed			-.729	20.395
Uncertainties	Equal variances assumed	4.124	.054	-.493	24
	Equal variances not assumed			-.671	21.985

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Risks	Equal variances assumed	.585	-.398	.719
	Equal variances not assumed	.475	-.398	.547
Uncertainties	Equal variances assumed	.627	-.391	.793
	Equal variances not assumed	.509	-.391	.582

Independent Samples Test

	t-test for Equality of Means	
	95% Confidence Interval of the Difference	
	Lower	Upper

Risks	Equal variances assumed	-1.883	1.086
	Equal variances not assumed	-1.538	.741
Uncertainties	Equal variances assumed	-2.028	1.246
	Equal variances not assumed	-1.599	.817

Table 16- Correlations: SLR, Storms and risks and uncertainties

Correlations

		Risks	Uncertainties	slr_ave_fre	slr_ave_sev
Risks	Pearson Correlation	1	.917**	.190	.093
	Sig. (2-tailed)		.000	.373	.697
	N	26	26	24	20
Uncertainties	Pearson Correlation	.917**	1	.226	.095
	Sig. (2-tailed)	.000		.288	.690
	N	26	26	24	20
slr_ave_fre	Pearson Correlation	.190	.226	1	.613**
	Sig. (2-tailed)	.373	.288		.004
	N	24	24	24	20
slr_ave_sev	Pearson Correlation	.093	.095	.613**	1
	Sig. (2-tailed)	.697	.690	.004	
	N	20	20	20	20
sto_ave_fre	Pearson Correlation	.455*	.368	.757**	.376
	Sig. (2-tailed)	.020	.065	.000	.102
	N	26	26	24	20
sto_ave_sev	Pearson Correlation	.241	.229	-.273	.777**
	Sig. (2-tailed)	.256	.282	.218	.000
	N	24	24	22	19

Correlations

		sto_ave_fre	sto_ave_sev
Risks	Pearson Correlation	.455*	.241
	Sig. (2-tailed)	.020	.256
	N	26	24
Uncertainties	Pearson Correlation	.368	.229
	Sig. (2-tailed)	.065	.282
	N	26	24
slr_ave_fre	Pearson Correlation	.757**	-.273
	Sig. (2-tailed)	.000	.218
	N	24	22

slr_ave_sev	Pearson Correlation	.376	.777**
	Sig. (2-tailed)	.102	.000
	N	20	19
sto_ave_fre	Pearson Correlation	1	-.104
	Sig. (2-tailed)		.627
	N	26	24
sto_ave_sev	Pearson Correlation	-.104	1
	Sig. (2-tailed)	.627	
	N	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 17- Correlations: SLR, Storms and risks and uncertainties on seaports

Correlations

		Sea_Risks	Sea_Uncert	Seap_slr_ave_fre	Seap_slr_ave_sev
Sea_Risks	Pearson Correlation	1	.923**	.150	-.073
	Sig. (2-tailed)		.000	.566	.812
	N	19	19	17	13
Sea_Uncert	Pearson Correlation	.923**	1	.186	-.037
	Sig. (2-tailed)	.000		.474	.904
	N	19	19	17	13
Seap_slr_ave_fre	Pearson Correlation	.150	.186	1	.527
	Sig. (2-tailed)	.566	.474		.064
	N	17	17	17	13
Seap_slr_ave_sev	Pearson Correlation	-.073	-.037	.527	1
	Sig. (2-tailed)	.812	.904	.064	
	N	13	13	13	13
Seap_sto_ave_fre	Pearson Correlation	.457*	.343	.779**	.128
	Sig. (2-tailed)	.049	.151	.000	.678
	N	19	19	17	13
Seap_sto_ave_sev	Pearson Correlation	.137	.130	-.503	.718**
	Sig. (2-tailed)	.599	.619	.056	.009
	N	17	17	15	12

Correlations

		Seap_sto_ave_fre	Seap_sto_ave_sev
Sea_Risks	Pearson Correlation	.457*	.137
	Sig. (2-tailed)	.049	.599
	N	19	17
Sea_Uncert	Pearson Correlation	.343	.130
	Sig. (2-tailed)	.151	.619
	N	19	17
Seap_slr_ave_fre	Pearson Correlation	.779**	-.503
	Sig. (2-tailed)	.000	.056
	N	17	15
Seap_slr_ave_sev	Pearson Correlation	.128	.718**
	Sig. (2-tailed)	.678	.009
	N	13	12
Seap_sto_ave_fre	Pearson Correlation	1	-.364
	Sig. (2-tailed)		.151
	N	19	17
Seap_sto_ave_sev	Pearson Correlation	-.364	1
	Sig. (2-tailed)	.151	
	N	17	17

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 18: Correlations: risks, uncertainties and SLR, storms on dry ports

Correlations

		Dryp_Risks	Dryp_Uncert	Dryp_slr_ave_fre	Dryp_slr_ave_sev
Dryp_Risks	Pearson Correlation	1	.842*	.429	.432
	Sig. (2-tailed)		.017	.337	.333
	N	7	7	7	7
Dryp_Uncert	Pearson Correlation	.842*	1	.501	.312
	Sig. (2-tailed)	.017		.252	.496
	N	7	7	7	7
Dryp_slr_ave_fre	Pearson Correlation	.429	.501	1	.828*
	Sig. (2-tailed)	.337	.252		.021
	N	7	7	7	7
Dryp_slr_ave_sev	Pearson Correlation	.432	.312	.828*	1
	Sig. (2-tailed)	.333	.496	.021	
	N	7	7	7	7

Dryp_sto_ave_fre	Pearson Correlation	.393	.433	.856*	.906**
	Sig. (2-tailed)	.383	.332	.014	.005
	N	7	7	7	7
Dryp_sto_ave_sev	Pearson Correlation	.486	.409	.510	.765*
	Sig. (2-tailed)	.269	.362	.242	.045
	N	7	7	7	7

Correlations

		Dryp_sto_ave_fre	Dryp_sto_ave_sev
Dryp_Risks	Pearson Correlation	.393	.486
	Sig. (2-tailed)	.383	.269
	N	7	7
Dryp_Uncert	Pearson Correlation	.433	.409
	Sig. (2-tailed)	.332	.362
	N	7	7
Dryp_slr_ave_fre	Pearson Correlation	.856*	.510
	Sig. (2-tailed)	.014	.242
	N	7	7
Dryp_slr_ave_sev	Pearson Correlation	.906**	.765*
	Sig. (2-tailed)	.005	.045
	N	7	7
Dryp_sto_ave_fre	Pearson Correlation	1	.682
	Sig. (2-tailed)		.091
	N	7	7
Dryp_sto_ave_sev	Pearson Correlation	.682	1
	Sig. (2-tailed)	.091	
	N	7	7

Table 19: T-Test: the means of impacts on Seaports with and without measure

Group Statistics

	Seap_Pro_Mea_1	N	Mean	Std. Deviation	Std. Error Mean
Seap_slr_fre_a	without measures	4	4.25	.957	.479
	with measures	12	4.58	.793	.229
Seap_slr_fre_b	without measures	5	4.80	.447	.200
	with measures	12	4.83	.577	.167
Seap_slr_fre_c	without measures	5	4.20	.837	.374
	with measures	12	4.42	.996	.288
Seap_slr_fre_d	without measures	5	4.20	.837	.374
	with measures	12	3.75	1.485	.429
Seap_slr_fre_e	without measures	5	4.20	1.095	.490
	with measures	12	5.00	.603	.174
Seap_slr_sev_a	without measures	4	4.50	1.000	.500
	with measures	6	4.67	.516	.211
Seap_slr_sev_b	without measures	4	4.75	.500	.250
	with measures	6	5.00	.632	.258
Seap_slr_sev_c	without measures	5	4.40	.894	.400
	with measures	7	4.29	.756	.286
Seap_slr_sev_d	without measures	5	5.00	.707	.316
	with measures	8	4.13	.835	.295
Seap_slr_sev_e	without measures	5	4.00	1.000	.447
	with measures	6	5.17	.753	.307
Seap_sto_fre_a	without measures	6	4.17	.408	.167
	with measures	13	4.31	.947	.263
Seap_sto_fre_b	without measures	6	3.67	1.211	.494
	with measures	13	4.38	1.044	.290
Seap_sto_fre_c	without measures	6	3.00	.632	.258
	with measures	12	4.08	1.165	.336
Seap_sto_fre_d	without measures	6	3.67	.816	.333
	with measures	13	4.77	1.013	.281
Seap_sto_sev_a	without measures	6	4.33	.516	.211
	with measures	8	4.38	.916	.324
Seap_sto_sev_b	without measures	4	3.75	.500	.250
	with measures	8	4.63	.744	.263
Seap_sto_sev_c	without measures	6	3.67	1.366	.558
	with measures	8	4.25	.707	.250
Seap_sto_sev_d	without measures	6	4.00	.632	.258
	with measures	8	3.75	2.121	.750

Table 20: T-Test: the significance of impacts on Seaports with and without measure

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Seap_slr_fre_a	Equal variances assumed	.172	.684	-.695	14	.499	-.333	.480	-1.362	.696
	Equal variances not assumed			-.628	4.465	.561	-.333	.531	-1.748	1.081
Seap_slr_fre_b	Equal variances assumed	.264	.615	-.115	15	.910	-.033	.290	-.652	.586
	Equal variances not assumed			-.128	9.771	.901	-.033	.260	-.615	.549
Seap_slr_fre_c	Equal variances assumed	.744	.402	-.426	15	.676	-.217	.509	-1.302	.868

	Equal variances not assumed			-.459	8.982	.657	-.217	.472	-1.285	.851
Seap_slr_fre_d	Equal variances assumed	1.694	.213	.630	15	.538	.450	.715	-1.074	1.974
	Equal variances not assumed			.791	13.151	.443	.450	.569	-.778	1.678
Seap_slr_fre_e	Equal variances assumed	7.273	.017	-1.962	15	.069	-.800	.408	-1.669	.069
	Equal variances not assumed			-1.539	5.045	.184	-.800	.520	-2.133	.533
Seap_slr_sev_a	Equal variances assumed	1.996	.195	-.351	8	.735	-.167	.475	-1.262	.929
	Equal variances not assumed			-.307	4.084	.774	-.167	.543	-1.661	1.328
Seap_slr_sev_b	Equal variances assumed	.022	.886	-.661	8	.527	-.250	.378	-1.123	.623
	Equal variances not assumed			-.696	7.615	.507	-.250	.359	-1.086	.586

Seap_slr_sev_c	Equal variances assumed	.240	.635	.240	10	.815	.114	.477	-.948	1.176
	Equal variances not assumed			.232	7.774	.822	.114	.492	-1.025	1.254
Seap_slr_sev_d	Equal variances assumed	.845	.378	1.941	11	.078	.875	.451	-.117	1.867
	Equal variances not assumed			2.023	9.766	.071	.875	.432	-.092	1.842
Seap_slr_sev_e	Equal variances assumed	.823	.388	-2.211	9	.054	-1.167	.528	-2.360	.027
	Equal variances not assumed			-2.150	7.357	.067	-1.167	.543	-2.437	.104
Seap_sto_fre_a	Equal variances assumed	6.242	.023	-.346	17	.734	-.141	.408	-1.001	.719
	Equal variances not assumed			-.453	16.996	.656	-.141	.311	-.797	.515
Seap_sto_fre_b	Equal variances assumed	.409	.531	-1.328	17	.202	-.718	.541	-1.859	.423

	Equal variances not assumed			-1.253	8.596	.243	-.718	.573	-2.023	.587
Seap_sto_fre_c	Equal variances assumed	3.896	.066	-2.107	16	.051	-1.083	.514	-2.173	.007
	Equal variances not assumed			-2.556	15.749	.021	-1.083	.424	-1.983	-.184
Seap_sto_fre_d	Equal variances assumed	.181	.676	-2.329	17	.032	-1.103	.473	-2.101	-.104
	Equal variances not assumed			-2.529	12.083	.026	-1.103	.436	-2.052	-.154
Seap_sto_sev_a	Equal variances assumed	1.638	.225	-.100	12	.922	-.042	.419	-.954	.870
	Equal variances not assumed			-.108	11.338	.916	-.042	.386	-.889	.806
Seap_sto_sev_b	Equal variances assumed	.612	.452	-2.101	10	.062	-.875	.416	-1.803	.053
	Equal variances not assumed			-2.411	8.733	.040	-.875	.363	-1.700	-.050

Seap_sto_sev_c	Equal variances assumed	.788	.392	-1.044	12	.317	-.583	.558	-1.800	.634
	Equal variances not assumed			-.954	7.009	.372	-.583	.611	-2.028	.862
Seap_sto_sev_d	Equal variances assumed	5.863	.032	.277	12	.786	.250	.902	-1.716	2.216
	Equal variances not assumed			.315	8.589	.760	.250	.793	-1.558	2.058

Table 21: T-Test: The mean of average impacts on Seaports with and without measures

Group Statistics

	Seap_Pro_Mea_1	N	Mean	Std. Deviation	Std. Error Mean
Seap_slr_ave_fre	without measures	5	4.3600	.38471	.17205
	with measures	12	4.5167	.74080	.21385
Seap_slr_ave_sev	without measures	5	4.4800	.54037	.24166
	with measures	8	4.5625	.58539	.20697
Seap_sto_ave_fre	without measures	6	3.6250	.26220	.10704
	with measures	13	4.3910	.96007	.26628
Seap_sto_ave_sev	without measures	6	3.9861	.54878	.22404
	with measures	11	3.9545	1.39561	.42079

Table 22: T-Test: The significance of average impacts on Seaports with and without measures

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means	
	F	Sig.	t	Df

Seap_slr_ave_fre	Equal variances assumed	2.830	.113	-.443	15
	Equal variances not assumed			-.571	13.869
Seap_slr_ave_sev	Equal variances assumed	.011	.918	-.254	11
	Equal variances not assumed			-.259	9.193
Seap_sto_ave_fre	Equal variances assumed	4.609	.047	-1.895	17
	Equal variances not assumed			-2.669	15.237
Seap_sto_ave_sev	Equal variances assumed	.982	.337	.053	15
	Equal variances not assumed			.066	14.192

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Seap_slr_ave_fre	Equal variances assumed	.664	-.15667	.35385
	Equal variances not assumed	.577	-.15667	.27447
Seap_slr_ave_sev	Equal variances assumed	.804	-.08250	.32462
	Equal variances not assumed	.801	-.08250	.31817
Seap_sto_ave_fre	Equal variances assumed	.075	-.76603	.40425
	Equal variances not assumed	.017	-.76603	.28699
Seap_sto_ave_sev	Equal variances assumed	.959	.03157	.60026
	Equal variances not assumed	.948	.03157	.47672

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Seap_slr_ave_fre	Equal variances assumed	-.91088	.59754
	Equal variances not assumed	-.74586	.43253
Seap_slr_ave_sev	Equal variances assumed	-.79699	.63199
	Equal variances not assumed	-.79996	.63496

Seap_sto_ave_fre	Equal variances assumed	-1.61891	.08686
	Equal variances not assumed	-1.37690	-.15515
Seap_sto_ave_sev	Equal variances assumed	-1.24786	1.31100
	Equal variances not assumed	-.98959	1.05272

Table 23: T-Test: The mean of impacts on dry ports with and without measures

Group Statistics

	Dryp_Pro_Mea_1	N	Mean	Std. Deviation	Std. Error Mean
Dryp_slr_fre_a	without measures	2	5.00	.000	.000
	with measures	5	4.60	.894	.400
Dryp_slr_fre_b	without measures	2	5.00	.000	.000
	with measures	5	4.40	.894	.400
Dryp_slr_fre_c	without measures	2	4.50	.707	.500
	with measures	5	4.80	.447	.200
Dryp_slr_fre_d	without measures	2	3.50	.707	.500
	with measures	5	4.80	.447	.200
Dryp_slr_fre_e	without measures	2	5.00	.000	.000
	with measures	5	4.40	.894	.400
Dryp_slr_sev_a	without measures	1	6.00	.	.
	with measures	4	5.25	.957	.479
Dryp_slr_sev_b	without measures	1	6.00	.	.
	with measures	5	5.20	.837	.374
Dryp_slr_sev_c	without measures	1	5.00	.	.
	with measures	4	5.25	.957	.479
Dryp_slr_sev_d	without measures	2	4.50	.707	.500
	with measures	4	5.25	.957	.479
Dryp_slr_sev_e	without measures	1	6.00	.	.
	with measures	4	5.00	1.155	.577
Dryp_sto_fre_a	without measures	2	4.50	.707	.500
	with measures	5	4.80	.447	.200
Dryp_sto_fre_b	without measures	2	5.00	.000	.000
	with measures	5	4.60	.548	.245
Dryp_sto_fre_c	without measures	2	4.50	.707	.500

	with measures	5	4.20	.837	.374
Dryp_sto_fre_d	without measures	2	5.00	.000	.000
	with measures	5	4.60	1.140	.510
Dryp_sto_sev_a	without measures	1	4.00	.	.
	with measures	4	5.25	.957	.479
Dryp_sto_sev_b	without measures	1	6.00	.	.
	with measures	4	4.75	.957	.479
Dryp_sto_sev_c	without measures	2	5.00	1.414	1.000
	with measures	5	4.80	.837	.374
Dryp_sto_sev_d	without measures	1	6.00	.	.
	with measures	4	5.00	1.155	.577

Table 24: T-Test: The significance of impacts on dry ports with and without measures

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Dryp_slr_fre_a	Equal variances assumed	2.540	.172	.598	5	.576	.400	.669	-1.321	2.121
	Equal variances not assumed			1.000	4.000	.374	.400	.400	-.711	1.511
Dryp_slr_fre_b	Equal variances assumed	6.090	.057	.896	5	.411	.600	.669	-1.121	2.321
	Equal variances not assumed			1.500	4.000	.208	.600	.400	-.511	1.711

Dryp_slr_fre_c	Equal variances assumed	.804	.411	-.703	5	.513	-.300	.427	-1.397	.797
	Equal variances not assumed			-.557	1.337	.656	-.300	.539	-4.155	3.555
Dryp_slr_fre_d	Equal variances assumed	.804	.411	-3.047	5	.029	-1.300	.427	-2.397	-.203
	Equal variances not assumed			-2.414	1.337	.196	-1.300	.539	-5.155	2.555
Dryp_slr_fre_e	Equal variances assumed	6.090	.057	.896	5	.411	.600	.669	-1.121	2.321
	Equal variances not assumed			1.500	4.000	.208	.600	.400	-.511	1.711
Dryp_slr_sev_a	Equal variances assumed	.	.	.701	3	.534	.750	1.070	-2.657	4.157
	Equal variances not assumed			.	.	.	.750	.	.	.
Dryp_slr_sev_b	Equal variances assumed	.	.	.873	4	.432	.800	.917	-1.745	3.345
	Equal variances not assumed			.	.	.	.800	.	.	.
Dryp_slr_sev_c	Equal variances assumed	.	.	-.234	3	.830	-.250	1.070	-3.657	3.157
	Equal variances not assumed			.	.	.	-.250	.	.	.
Dryp_slr_sev_d	Equal variances assumed	.667	.460	-.961	4	.391	-.750	.781	-2.917	1.417
	Equal variances not assumed			-1.083	2.870	.361	-.750	.692	-3.011	1.511
Dryp_slr_sev_e	Equal variances assumed	.	.	.775	3	.495	1.000	1.291	-3.109	5.109
	Equal variances not assumed			.	.	.	1.000	.	.	.
Dryp_sto_fre_a	Equal variances assumed	.804	.411	-.703	5	.513	-.300	.427	-1.397	.797

	Equal variances not assumed			-.557	1.337	.656	-.300	.539	-4.155	3.555
Dryp_sto_fre_b	Equal variances assumed	34.286	.002	.976	5	.374	.400	.410	-.654	1.454
	Equal variances not assumed			1.633	4.000	.178	.400	.245	-.280	1.080
Dryp_sto_fre_c	Equal variances assumed	.186	.684	.441	5	.677	.300	.680	-1.447	2.047
	Equal variances not assumed			.480	2.257	.674	.300	.624	-2.114	2.714
Dryp_sto_fre_d	Equal variances assumed	4.165	.097	.469	5	.659	.400	.853	-1.793	2.593
	Equal variances not assumed			.784	4.000	.477	.400	.510	-1.016	1.816
Dryp_sto_sev_a	Equal variances assumed	.	.	-1.168	3	.327	-1.250	1.070	-4.657	2.157
	Equal variances not assumed			.	.	.	-1.250	.	.	.
Dryp_sto_sev_b	Equal variances assumed	.	.	1.168	3	.327	1.250	1.070	-2.157	4.657
	Equal variances not assumed			.	.	.	1.250	.	.	.
Dryp_sto_sev_c	Equal variances assumed	1.231	.318	.244	5	.817	.200	.820	-1.907	2.307
	Equal variances not assumed			.187	1.293	.876	.200	1.068	-7.879	8.279
Dryp_sto_sev_d	Equal variances assumed	.	.	.775	3	.495	1.000	1.291	-3.109	5.109
	Equal variances not assumed			.	.	.	1.000	.	.	.

Table 25: T-Test: The mean of average impacts on Dry ports with and without measures

Group Statistics

	Dryp_Pro_Mea_1	N	Mean	Std. Deviation	Std. Error Mean
Dryp_slr_ave_fre	without measures	2	4.6000	.28284	.20000
	with measures	5	4.6000	.58310	.26077
Dryp_slr_ave_sev	without measures	2	5.2000	.28284	.20000
	with measures	5	5.1600	.85323	.38158
Dryp_sto_ave_fre	without measures	2	4.7500	.00000	.00000
	with measures	5	4.5500	.37081	.16583
Dryp_sto_ave_sev	without measures	2	4.7500	1.06066	.75000
	with measures	5	4.9500	.71589	.32016

Table 26: T-Test: The significance of average impacts on dry ports with and without measures

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	T	Df
Dryp_slr_ave_fre	Equal variances assumed	.510	.507	.000	5
	Equal variances not assumed			.000	4.232
Dryp_slr_ave_sev	Equal variances assumed	2.433	.180	.062	5
	Equal variances not assumed			.093	4.992
Dryp_sto_ave_fre	Equal variances assumed	2.278	.192	.721	5
	Equal variances not assumed			1.206	4.000
Dryp_sto_ave_sev	Equal variances assumed	.606	.472	-.300	5
	Equal variances not assumed			-.245	1.386

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
Dryp_slr_ave_fre	Equal variances assumed	1.000	.00000	.44900
	Equal variances not assumed	1.000	.00000	.32863
Dryp_slr_ave_sev	Equal variances assumed	.953	.04000	.64721

	Equal variances not assumed	.930	.04000	.43081
Dryp_sto_ave_fre	Equal variances assumed	.503	.20000	.27749
	Equal variances not assumed	.294	.20000	.16583
Dryp_sto_ave_sev	Equal variances assumed	.776	-.20000	.66671
	Equal variances not assumed	.838	-.20000	.81548

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
Dryp_slr_ave_fre	Equal variances assumed	-1.15419	1.15419
	Equal variances not assumed	-.89302	.89302
Dryp_slr_ave_sev	Equal variances assumed	-1.62370	1.70370
	Equal variances not assumed	-1.06794	1.14794
Dryp_sto_ave_fre	Equal variances assumed	-.51331	.91331
	Equal variances not assumed	-.26042	.66042
Dryp_sto_ave_sev	Equal variances assumed	-1.91383	1.51383
	Equal variances not assumed	-5.71260	5.31260