How is Business Adapting to Climate Change Impacts Appropriately? Insight from the Commercial Port Sector

1. Introduction

Climate change is at the forefront of research due to its potential catastrophic impacts to human welfare. There is no doubt that effective adaptation to climate change impacts is a key research topic in business ethics that will pose substantial implications on the good lives of human beings both in the short and long-term future. In this case, the commercial port sector is a highly relevant sector that is worthy for us to pay specific attention. First, with the increasingly pivotal role of ports in logistics, supply chains, and international trade nowadays (Ng and Liu, 2014), the study of ports in adapting to climate change impacts will not only enhance ports' planning quality, but also boost the efficient operation of transportation, logistics, supply chains, and the well being of global and regional economies. Second, ports have very close relationship with cities and regions that persist until today (Hall and Jacobs, 2012). The numerous urban, economic, and social activities within ports and port areas (both directly and indirectly) imply that effective climate adaptation planning by ports would secure good human livelihoods in general, present and the future. There is a very urgent need to investigate whether ports' planning approach is appropriate that can lead to effective adaptation to climate change impacts.

Hitherto, adaptation to climate change impacts by ports is an under-researched topic (Ng et al., 2016a). As noted by the US National Research Council (NRC), there is insufficient research focusing on the decision-making aspect of climate adaptation planning in general (NRC, 2010). This, together with diversified interpretation on climate change impacts on ports between port authorities, private operators, and other port stakeholders on the risk and uncertainties of climate change, ensures that getting all stakeholders to agree on a unified approach on planning, such as how adaptation measures should be developed and implemented, is difficult and complex. Even for port planners and operators who have taken countermeasures to climate change impacts on respective ports, they tend to focus on mitigation (e.g., reduce greenhouse gas (GHG)) rather than adaptation. With the strong wave of neoliberal reforms among global ports throughout the past decades, such as privatization of terminal management (Ng and Pallis, 2010), the barriers that prevent ports to plan for effective adaptation measures are rapidly piling up. As Knatz (2016) points out, why should a (private) port/terminal operator make investments on waterfront properties that would benefit the future holder of the concession? Even if they are willing to do so, given the nature of climate change impacts that usually involve a long timeframe (compared to port planning and the duration of most concession agreements), how can they evaluate the outcomes of adaptation efforts, and justify that 'money has been well spent'?

This ethical dilemma is caused by what economists called 'externalities', defined by Abelson (2002) as 'any positive or negative effect that market exchanges have on firms or individuals who do not participate directly in those exchanges'. Extensive literature has identified externalities as a major source for business ethics. As Cosans (2009) points out, 'any practice, which has a negative externality that requires another party to take significant loss without consent or compensation, can be seen as unethical'. A reverse of the logic can be used to support social entrepreneurship that generates positive externalities (Santos, 2012). Social responsibility, a major concern of business ethics, is closely related to the externalities created by company activities (see Jones, 1999; Haigh and Hazelton, 2004; Shum and Yam, 2011). The externalities of ports' climate adaptation planning are complex and multi-layered. In particular, three dimensions of externalities exist in the issue: time, space and management. Time is due to the nature of climate adaptation planning. As discussed earlier, a (private) terminal operator would constantly be plagued by the trade-off between short-term investment and long-term effect, especially when facing the possible change of ownership/exclusive operating rights in the future. Against this backdrop, myopic behavior, i.e., underinvestment in climate adaptation, would likely emerge. For space, it consists of two levels: vertical and horizontal. Vertically, under the current paradigm, in most cases, port/terminal operators have to take all the responsibilities for investment for climate adaptation, while other stakeholders within and around the port (e.g., real estate developers, hinterland infrastructure owners) can benefit from the planning and investment. In other words, when they decide how and when to invest in climate adaptation planning, they take into account all the costs but only part of the benefits, thus inducing an investment lower than the socially optimal level. This is similar to the environmental concern in the general business literature (e.g., see Mathews, 1995; Asgary and Mitschow, 2002; Cambra-Fierro et al., 2008), and would potentially cause a similar dilemma. Horizontally, ports are not standalone fortresses, but nodes in a complex trade and logistics network (Ng and Liu, 2014). Therefore, the disruption of ports' operation due to climate change affects not only the immediate surrounding region, but also remote regions through the disruptions of other ports' operations - the so-called 'knock-on' effect (Jiang et al., 2015). With climate adaptation planning and investment in place, certain port/terminal operators have bear all the costs while others can 'free-ride', further distorting the incentive for investment.

For management, it is the classical 'principal-agent problem'. Terminal operations, like other business sectors, need to have people or entities (the 'agent', in this case port managers) to make decisions on behalf of the real owners (the 'principal', all the people in the country and all the shareholders for public and private ports/terminals, respectively). This dilemma exists because sometimes the agents are motivated to act in their own best interest rather than those of the principals. Bøhren (1998) illustrates that ethical issues would naturally arise under a principle-agent setting. It can be particularly severe in a port's climate adaptation planning, given its long-term nature and the substantial uncertainties involved. Consider the case where substantial money has been committed in a climate adaptation program. If no natural disaster ever happens during the port manager's tenure, he/she would likely be accused of wasting valuable resources in doing something meaningless; even if such a disaster does happen and the measures help to fend it off, still, his/her contribution may be discredited because the huge loss avoided thanks to the program never really comes in tangible forms. This creates the 'goalkeeper's dilemma' (Chiappori, 2002): the agent might know the best strategy, but in action they pick a sub-optimal strategy instead so as to shun the worst scenario for themselves.

The above dilemma highlights the importance of evaluating whether the current planning practice of ports, including its approach, process, and system, is appropriate in tackling climate change impacts effectively; and if not, how it should be reformed. Port planning nowadays is largely a business decision-making activity closely knitted to the principal-agent problem; and so the attitude and behaviors of port planners and operators, notably how climate change impacts should be tackled under time and budgetary constraints, will significantly shape planning approach, process, and indeed, outcomes. Thus, in order to understand the whole issue, we must first conduct deep investigation on the current attitude and behaviors of port planners and operators (including policymakers and port/terminal operators, both public and private) on ports' climate adaptation planning.

Understanding such, through investigating the perception of key port planners and operators from 21 selected ports[1] (that include seaports and dry ports, see below) in Canada, the paper studies the attitude and behaviors of port planners and operators on ports' climate adaptation planning so as to tackle climate change impacts, notably its risks and uncertainties[2], on ports. With ports located along the country's long coastline under different climatic zones, the impacts of climate change on different Canadian ports are highly diversified. Thus, we believe that the focus on Canadian ports can generate useful insight to global ports that are (will be) impacted differently by climate change. Against this background, this study addresses four major research questions:

1) How effectively do adaptation measures address climate change impacts? (Q1)
2) What are the similarities and differences of climate change impacts to different types of ports (i.e., seaports and dry ports)? (Q2)

[1] This study focused on commercial ports handling cargoes (e.g., containers, liquid bulk). Ports that handled passengers (e.g., cruise), or non-commercial purposes (e.g., naval), were not included.

[2] In this study, risk is 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'. Meanwhile, uncertainty is understood as 'the propensity or predisposition to be adversely affected, including the characteristics of a person or group that influences their capacity to anticipate, cope with, resist, and recover from the adverse effects of physical events'. For further details, see IPCC (2012).

3) What are the main impacts of climate change on ports? (Q3)
4) What are the major challenges in adapting to climate change for ports, especially under the established institutional systems in planning? (Q4)

Based on these questions, the study aims to fulfill four major objectives:

1) To investigate the effectiveness of adaptation measures, and the current situation and differences or similarities of ports in implementing adaptation strategies;
2) To assess the attitude and behaviors of port planners and operators on climate change risks and uncertainties, including their perception of climate change impacts on port operation, performance, and infrastructures;
3) To anticipate the potential influences if adaptation measures are conducted among ports in the foreseeable future; and
4) To understand the important aspects and factors in formulating plans for ports to adapt to climate change impacts.

Understanding the kaleidoscopic nature of climate change impacts on ports (Ng et al., 2016b), we target ports located in different areas around Canada with diversified impacts posed by climate change so as to averse subjective bias, and enables it to reflect the situation more accurately. Also, in this study, ports are divided into 'seaports' and 'dry ports' (also called 'inland terminals', see Roso, 2007). Often located along the most vulnerable areas, seaports are susceptible to the climate-associated impacts, notably sea level rise (SLR), high winds, and storm surges (Hanson and Nicholls, 2012; Asariotis and Benamara, 2012). On some areas, seaports are affected by different challenges, such as muskeg and permafrost (e.g., port of Churchill in northern Canada). Also, it is extremely important to include dry ports as a separate category. Seaports and dry ports share many similarities (e.g., the need for capital-intensive infrastructures and facilities in operations) (Ng and Liu, 2014), and complement each other (e.g., relieving port congestion, air pollution, accidents) (Rahimi et al., 2008; Roso, 2008; Wang and Wei, 2008). Similar to seaports, climate change plays significant roles in dry port operations, especially on facilities related to access and connections to/from the dry ports (Wang, 2015). However, the impacts of climate change on seaports and dry ports differ in many aspects. For instance, while SLR poses major challenges on many seaports, it is unlikely to impact dry ports due to their long distance away from shorelines. Thus, the perception of dry port planners on climate change impacts, and how to adapt to them, would differ significantly from their seaport counterparts. Interestingly, hitherto, there are very few studies that focus on the risks and uncertainties of climate change on dry ports. The inclusion of dry ports would make this study more comprehensive and complete.

The rest of the paper is structured as follows. The literature review can be found in section 2, while section 3 explains the process of data collection. The analytical results are presented in section 5, while the discussions and conclusion can be found in sections 6 and 7, respectively. For the rest of the paper, unless otherwise stated, 'port' is understood as a generic term that includes both seaports and dry ports.

2. Literature review

There is a scarcity of research focusing on climate change impacts on the economy and environment of ports, whose impacts are numerous and would persist for months or even years. A major issue was the study focus: previous research tended to prioritize on mitigation. This was not surprising with the existence of many more anticipated regulations or global attention (Becker et al., 2012), and there was substantially more research on measuring and controlling GHG (e.g., Patterson et al., 2008) and de-carbonization (Geels, 2012; Schwanen et al., 2012; Watson, 2012). Overlooking adaptation was a significant gap, as proactive adaptation to minimize vulnerabilities could be far more cost-effective than mitigation or reactive strategies (Pielke, 2007; Stern and Britain 2006). Also, as mitigation could not address all the deleterious risk, it might already be too late to avoid all deleterious climate change impacts (Applegate, 2010). Even among research focusing on adaptation, most tend to limit to physical engineering (e.g., technical details on the construction of dykes and levees) (Ng et al., 2016b).

The ignorance of climate change adaptation clearly affects the direction of port management. In the past decade, several research studies on climate change impacts on ports had been conducted (Becker et al., 2011). In 2005 and 2006, the Texas A&M University conducted a survey entitled *Port Planning and Views on Climate Change* on 27 US seaports focusing on the question: ‘is planning for climate change on the radar screen of the USA seaport industry?’ (Becker et al., 2011). They found that while many managers realize the potential perils of climate change on port operations, most of them hardly take any adequate measures, or even initial steps, to address this problem. In California, two similar studies suggest that the expected risks of climate change and SLR on maritime facilities are generally ignored, even though SLR was anticipated to reach 1.4 meters by 2100 (CSLC, 2009). Another one was conducted by Becker et al. (2011) using a survey to deal with knowledge, perceptions, and planning effects among seaport managers around the world. They summarized several questions on climate change impacts, and port adaptation strategies and planning. They found that nearly 50% of the respondents believe that climate change would pose negative impacts on their operations in the coming decade, but 66% feel that they are inadequately informed on the extent of such impacts. A similar study on Australian ports by Ng et al. (2013) has led to a similar conclusion.

Such a scarcity in research has created considerable handicaps that prevent ports from tackling the problem effectively. Some ports have already recognized this problem, and attempt to propose some adaptation strategies. For instance, the port of San Diego’s *Climate Mitigation and Adaptation Plan* (CMAP) was an attempt to develop a solid framework to deal with climate change impacts that considered the likelihood and consequence of impacts, and prioritized them by risk levels. However, ports are located within specific geographical settings, and so planning (including climate adaptation planning) is largely left to local planners, and is often done within a much shorter timeframe (≤ 20 years) than would be relevant to planning in the context of climate change. Port planning is highly institutionalized and ‘path dependent’, heavily constrained by local, well-established rules, procedures, and practices. Some scholars have warned that deficiencies within the institutional systems can slow down or prevent effective climate adaptation (e.g., Benson, 2010; Keohane and Victor, 2010; Wheeler et al., 2009). When undertaking unprecedented climate adaptation planning, ports often choose to ‘go it alone’ based on established approach. For example, the suggested adaptation measures may be based on the ‘benchmark setting’ (e.g., reduce GHG) approach of climate mitigation, while overlooking that similar benchmarks are far more difficult to establish for adaptation. The established approach could be inappropriate for adapting to climate change impacts also because while local policymakers and stakeholders undertake most port planning decisions, adapting to climate change impacts is far from just being ‘local’. Nowadays, port is a complex community of business and activities (Martin and Thomas, 2001) that involves transport, logistics, supply chain, and other sectors, and climate change impacts bear out differently to different port stakeholders (e.g., shipping network, access to ports, such as rail and trucks). Thus, together time and budgetary constraints, inter-port competition (Ng and Liu, 2014), and the lack of precedents push port planners and operators to undertake strategies based on short-term political and economic priorities, rather than meaningful long-term planning. Of course, the port sector is far from being the exception. In the Australian wine industry, for instance, Galbreath (2011) found that while many senior managers understand and pay attention to climate change impacts, still, the predominant interest is to assure maximum returns for shareholders and financial performance. The likely outcome is that many efforts spent in climate adaptation planning would be difficult, if not impossible, to implement. In fact, several failed cases can already be identified. For example, as described by Messner et al. (2016), after years of preparation, the port of San Diego suspended the adaptation components of the CMAP only less than a year after its introduction in 2013, in part thanks to the difficulty in mobilizing other port stakeholders to cooperate and comply with the suggested adaptation measures.

Yet these failed cases should hardly raise any eyebrows. The (still) rather implicit nature of climate change impacts and the uncertain effectiveness of adaptation measures imply that the critical juncture that catalyzes changes does not exist, or rather ‘fuzzy’. Together with ports’ ‘go it alone’ approach that is mainly path-dependent and embedded within certain institutional systems, the leeway for compromises between port authorities, private operators, and other port stakeholders in adjusting the *status quo* for (potentially) better adaptation frameworks becomes very narrow if not unavailable. Also, as Gutmann and Thompson (2012) point out, the cost of compromising (e.g., impacts of adaptation measures, the sacrifice made to implement adaptation measures) is not necessarily equally shared among stakeholders, while the lack of the stated critical juncture has made the option of maintaining the *status quo* more defensible. When the *status quo* remains intact, the consequence is that, despite recognizing the peril (i.e., climate change impacts on ports), port planners and operators would either choose to: 1) ignore the problem; or 2) carry out incremental measures that would, as described by Moser and Boykoff (2013), 'mainstream' climate adaptation into conventional planning system, practice, and process. This leads to the proposition that a paradigm shift in climate adaptation planning, in terms of both the planning approach and process, is required. If this is true, it simultaneously implies the need to adjust the established institutional systems in ports. Given the scarcity of research in ports' climate adaptation planning, let alone the relevance of port's institutional system in climate adaptation planning, further research is required to verify its relevance. But beforehand, we must first understand the attitude and behaviors of port planners and operators on climate adaptation planning under time and budgetary constraints. Specifically, it should focus on the factors that shape attitude and behaviors, and propose appropriate solutions that can overcome any potential barriers to effective climate adaptation planning.

3. Data collection

Data collection for this study involved a major survey targeting appropriate personnel investigating their current attitude towards ports' climate adaptation planning. As mentioned in section 1, 'ports' are divided into seaports and dry ports. The population of ports is 'those that were engaged in facilitating the transport of cargoes' (Becker et al. 2011, pp.11). The *World Port Source* (World Port Source, n.d.) was used to select the study samples. Considering the uniqueness and complexity of climate change impacts on different types of ports (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 was utilized. The selection was based on three main criteria, namely: 1) large and medium sized ports (i.e., the most heavily used ports in the list of *World Port Source*); 2) a geographical balance throughout Canada; and 3) members of the two major port associations in Canada (Association of Canada ports Authorities (ACPA) and Green Marine in Canada. These organizations were the foremost port organizations within Canada, and their networks and advice ensured that only the sources that were the most knowledgeable and authoritative to the research topic in question would be involved in this study.

A sample of 30 ports in Canada was identified (some illustrative examples included port of Montreal, CentrePort Canada, port of Sydney (NS), Windsor Port Authority, port of Churchill, CentrePort Canada, Iqaluit Harbor, Tuktogaktak Harbor, and Nanisvik Harbor)[3]. After then, the snowball sampling technique was applied to identify the appropriate port planners and operators within these ports (e.g., Vice-Presidents of port authorities, Operations Directors of terminal operators, Senior Planners, etc.). Recognizing the potential small sample size due to the very nature of this study beforehand[4], we especially paid much attention to the identification process so that only the most appropriate people were invited. In general, all the survey respondents shared similar characteristics: 1) they were the key decision-makers, and thus would play key roles in deciding the development direction of respective ports; 2) they were involved in the operations, and/or financial strategies and planning of respective ports (focusing on the environmental aspect); and 3) they had been on their current positions for at least five years, thus ensuring that they clearly understood how their respective organizations functioned. Finally, 50 relevant personnel from the selected ports were identified, contacted, and invited to complete the survey. Our choices were further verified through informal discussions with relevant scholars and senior practitioners within the port sector (e.g., senior officials from port authorities and terminal operators). To avoid over-representation from particular port(s), we contacted no more than two people from each port.

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[3] Not all the identities of the selected ports are illustrated here, as some respondents have reflected their concern, where they regarded the information that they have provided as sensitive and confidential.

[4] In most ports, only 1-4 people would be directly responsible for the environmental aspects of planning and strategic development. Among them, only 1-2 would hold senior managerial positions that would participate in the key decision-making process of ports.

The identified personnel were invited to complete an online questionnaire[5] dedicated for this study (Appendix A). The questions were divided into two types: closed-ended questions, which utilized Likert-scale multiple choices to quantify responses; open-ended questions, which provided more freedom to respondents to provide comments on various issues related to the study. The survey data was conducted between the summer of 2014 and early 2015, with 26 completed, valid responses (out of 32 replies) from 21 ports available for further processing and analysis.

To further enhance our understanding on the analyzed results, notably the factors that shaped the attitude and behaviors of respondents, we conducted 12 semi-structured, in-depth interviews with relevant scholars, policymakers, industrial practitioners, and other stakeholders (e.g., chairmen of professional associations and environmental groups) relevant to this topic. Among this group, several of them actually participated in the survey (thus able to explain their choices in more details), while the rest gave us a 'third eye' insight on the issue in question.

4. Quantitative analysis and hypotheses testing

4.1. Hypotheses

Based on the research objectives, we propose three hypotheses to address the first two research questions (Q1 and Q2), as follows:

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. (H1)
2) Adaptation measures and the existing impacts of the climate change on ports are positively relevant: there were more adaptation measures that have been

[5] In several cases, due to the preference of respondents, e-mails or phone calls were used instead.

implemented if there have been more risks and uncertainties on ports posed by climate change in the past decade. (H2)

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 those on a seaport in the past decade. (H3)

SPSS was used to run the statistical tests. *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). Also, *t*-test was applied to examine the statistical significance of risks and uncertainties posed by climate change on seaports and dry ports (hypothesis 3). The detailed test results can be found in Appendix B.

4.2. Hypotheses testing

We code all the 'grades' from 1 to 5 in each category, and the corresponding 'linguistic terms' and 'description' in measuring 'frequency', 'severity of consequence', 'timeframe', 'likelihood of consequence' and 'financial cost of adaptation measures' can be found in Tables 1, 2, 3, 4, and 5.

[INSERT TABLE 1 ABOUT HERE]

[INSERT TABLE 2 ABOUT HERE]

[INSERT TABLE 3 ABOUT HERE]

[INSERT TABLE 4 ABOUT HERE]

[INSERT TABLE 5 ABOUT HERE]

T-test is used to handle the data in H1. Here, the dependent variables are the impacts of climate change: (1) SLR and storm, measured by frequency and severity of consequences in the Q4 and Q5 (SLR impacts/increased intensity and/or frequency of high winds and/or storms in the past five years*;* (2) 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 ten years?): 1 to 9: 1 to 9 types of risks/and uncertainties.* The independent variable was the adaptation measure , 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*. We code all the data by categories (e.g., *SLR frequency a*). The results in Appendix B Table 1 indicate that there is no significant difference between the data with and of without measures, and the impacts of SLR and storms are '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 is 'minor' (M=4.33>4), but with adaptation measures is '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 is 'seldom' (M=4.12>4). Appendix B Table 2 shows that each p value is greater than 0.05 which suggests there is no statistically significant difference of SLR and storms impacts with and without measures.

After having the data averaged in each category, we obtain the averaged mean and the sig (2-tailed) of frequency and severity of SLR and storms. The results show that the average impacts of SLR and storms are 'seldom' and 'minor' in terms of frequency and severity of consequences. Meanwhile, there is no significant difference between the data of with and of without measures. Only in *storms average frequency*, the storms frequency without measures was 'sometimes' (M=3.9375>3), but with measures is 'seldom' (M=4.4722>4). Meanwhile, each p value is greater than 0.05, which represents that there is no statistically significant difference of SLR and storms impacts with and without measures. Thus, there is no statistically 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 average values under the categories of frequency and severity of consequences. The adaptation measures do not pose obvious effects in addressing the impacts posed by SLR and storms; the impacts of SLR and storms are ‘seldom’ and ‘minor’ in ‘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 are analyzed. As illustrated in Appendix B Tables 3 and 4, the mean values of the involved items are: $M_{\text{risks- without measures}} = 1.25$, $M_{\text{risks- with measures}} = 2.94$, $M_{\text{uncertainties- without measures}} = 2.00$, $M_{\text{uncertainties- without measures}} = 3.44$. The sig (2-tailed) values are: $F_{\text{risks}} (1, 26) = 1.349$, $P_{\text{risks}} = 0.010 < 0.05$, $F_{\text{uncertainties}} (1, 26) = 0.225$, $P_{\text{uncertainties}} = 0.052 > 0.05$). This means that there is significant difference of risks with and without adaptation measures, but there is no significant difference of uncertainties with and without adaptation measures. Meanwhile, the bootstrap result shows that there is significant difference between risks with and without adaptation measures (0.005), but there is no significant difference between uncertainties with and without adaptation measures. In other words, the ports that have undertaken adaptation measures in the past decade have fewer risks, but do not necessarily have fewer uncertainties. Hence, H1 is partially confirmed.

Regression analysis was utilized in testing H2 through examining the relationship between the number of measures have been taken and risks occurred, and the uncertainties occurred in the past decade respectively. First, the ten items in Q6 as 6a, 6b…6j and the 10 items in Q7 as 7a, 7b…7j are coded in order. The number in each questions represent the number of measures that had been undertaken in the past decade. Similarly, for H2, the dependent variable is the number of adaptations measures implemented in the past decade measured by the number of items choose in Q14: *1 to 12 adaptation measures*. While the independent variables are 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.

Based on the results, we conclude that the number of measures taken is positively related to the number of risks and negatively related the number of uncertainties and in the past decade. However, the bootstrap data shows that $P_{\text{risks-with measure}} = 0.000 < 0.05$, $R^{\wedge}_{\text{risks-with measure}} = 0.526$, $B_{\text{risks-with measure}} = 0.832$, and $P_{\text{uncertainties-with measure}} = 0.004 < 0.05$, $R^{\wedge}_{\text{uncertainties-with measure}} = 0.293$, $B_{\text{uncertainties-with measure}} = 0.564$. To summarize, the number of adaptation measures implemented is positively relevant to the number of risks, but not significantly relevant to the number of uncertainties pose by climate change in the past decade. Hence, H2 is partially confirmed.

After then, we figure out the implementation of protective measures of seaports and dry ports. The results show that the number of adaptation measures is 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; the number of measures is positively related to the number of risks and negatively related the number of uncertainties on the dry ports in the past decade (Tables 5 and 6 in Appendix B). Bootstrap results show a different result: for seaports, the number of measures is positively related to the number of risks and uncertainties on dry ports in the past decade; for dry ports, the number of adaptation measures is 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, we conclude that there is a positive relationship between the number of measures and the number of risks for both seaports and dry ports in Canada. However, the relationship between the number of measures and the number of uncertainties is not significant. More adaptation measures would have been undertaken if there is more risk occurred in the past decade, no matter seaports or dry ports. This implies that port planners and operators put more focus on the risk, rather than uncertainties, posed by climate change with the implementation of more adaptation measures. This further confirms H2.

After then, *T*-test is conducted to investigate different impacts of climate change on Canadian ports (H3). Here the independent variable is the type of ports (seaports or dry ports), which are 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 are analyzed. By utilizing *t*-test, the mean values and the sig (2-tailed) value of every item are obtained (Tables 7 and 8 in Appendix B). For each item in SLR and storms, in overall, the frequency of SLR and storms is 'seldom', and the severity of consequences is 'minor' (3<M<5). Even though there were several differences in terms of the mean value (e.g., in *SLR frequency d (Deposition and sedimentation occurred along your port/terminal's channels),* and *storms frequency c (Your port/terminal operation was shut down due to higher winds and/or storms),* and *storms severity d (Overland access to your port/terminal was limited due to higher winds and/or storms).* These indicate that each *p* value is greater than 0.05, and so there is no statistically significant difference of every item in SLR and storms impacts on seaports and dry ports.

Summarizing the results of mean and *p* values, there is statistically significant difference between seaports and dry ports in terms of SLR average severity: it is much more severe on seaports (*Seaport in SLR severity (a, b, c, d and e)* (M=4.60, 4.90, 4.33, 4.46, 4.64>4). The impact on dry ports ranges from "minor" to "negligible" (M=5.40, 5.33, 5.20, 5.00, 5.20>=5)). Moreover, the bootstrap results are consistent with the following conclusion: there is neither statistically significant difference on seaports and dry ports by examining the every item in SLR or in storms except in storm frequency *c ('Your port/terminal operation was shut down due to higher winds and/or storms')*. However, the result of average impacts of SLR and storms demonstrate that there is statistically significant different between seaports and dry ports ($P_{slr\_ave\_sev}=0.050$, $P_{sto\_ave\_fre}=0.003$, $P_{sto\_ave\_sev}=0.013 <= 0.05$). Besides SLR and storms, the difference of general risks and uncertainties is examined between seaports and dry ports. Likewise, we conclude that there is neither statistically significant difference between types and risks nor between types and uncertainties. Meanwhile, they confirm the non-significance between types and risks and uncertainties. In other words, the impacts of climate change pose little difference between seaport and dry port with respect to risks and uncertainties. Thus, H3 is partially confirmed.

4.3 Hypothesis re-testing

In retrospect, we notice that the moderate effects of protective measures are different in terms of the number of the used measures (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 mean values of frequency and severity), the results are so diversified that partially confirm H1, H2, and H3. Thus, we should consider whether SLR and storms, being two of the most commonly perceived 'primary' impacts of climate change to ports (e.g., see Becker et al. 2012), can represent the overall situation of climate change impacts to ports, and whether SLR and storms are related to risks and uncertainties. Moreover, since there are diversified impacts of climate change on seaports and dry ports (H3), the previous hypotheses should be re-tested on seaport and dry ports.

To examine the relationship between SLR, storms and risks and uncertainties, correlation analysis is utilized. Similarly, the impacts of SLR and storms are measured by the average values in frequency and severity of consequences in Q4 and Q5, and the risks and uncertainties are measures by the number of items being chosen in Q6 and Q7. The results indicate that there is a 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 is no significant correlation between them in terms of risks and uncertainties (Table 9 in Appendix B). The bootstrap result suggests that there is no significant correlation between SLR, storm and risks and uncertainties at the 0.05 level (2-tailed) (all $p>0.05$). Accordingly, we conclude that there is no obvious correlation between SLR, storms, and risks and uncertainties, and thus SLR and storms have no obvious correlation with the risks and uncertainties so as to be the primary representatives of climate change impacts to ports. Meanwhile, the findings justify the diversified results in H1 and H3: there is neither significant difference with and without measures in terms of SLR and storms, nor uncertainties, while there is significant difference in risks; there is some significant difference between seaport and dry ports in terms of average frequency and severity of SLR and storms, while there is neither significant difference in terms of every items in SLR and storms nor risks and uncertainties.

Understanding such, the previous hypotheses are further tested by dividing ports into seaport and dry ports. We found that, in 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) ($P=0.049<0.05$). This suggests that in seaports, to some extent, risks and uncertainties are interdependent or hard to distinguish, and SLR and storms are partially relevant with risks and uncertainties. Therefore, we conclude that SLR and storms cannot fully represent the climate change impacts on seaports. For dry ports, risks and uncertainties have 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 are related to risks and uncertainties, and like seaports, they cannot represent the climate change impacts on dry ports. Furthermore, bootstrap results confirm that risks and uncertainties have 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 are no significant correlations between SLR, storms, and risks and uncertainties on seaports and dry ports. The results from these tests are consistent with our previous conclusion that SLR and storms are partially related to risks and uncertainties, and represented the primary climate change impacts on seaports, but they have no obvious relation to risks and uncertainties on dry ports. This further clarifies our judgments to HI and H3.

Following the above, H1 is further tested on seaports and dry ports respectively. We first examine the effects of measures on seaports: although all the data are between 3 and 5, there are ten groups of data in the different range of mean values. Compared with the mean results in H1, there are more varieties with and without measures on seaports than on the combination of seaports and dry ports. Simultaneously, the majority *p* value is greater than 0.05, which represent that there is no significant statistical difference of SLR and storms impacts between with and without measures. However, there is 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, the average impacts of SLR are ‘seldom’ and ‘minor’ in terms of frequency and severity of consequences. However for storms, the storms average frequency without measures is ‘sometimes’ while with measures is ‘seldom’; the data in storms average severity with and without measures are both ‘minor’. Meanwhile, it indicates the difference in storms average frequency that there is significant statistical difference in storms average frequency with and without measures on seaports ($p=0.017<0.05$).

For dry ports, nearly all the mean values are greater than 4, and most data is in the different range of mean values. Compared with the mean values in H1, there are more varieties with and without measures on dry ports than on the combination of seaports and dry ports. As majority *p* value is greater than 0.05, there is no significant statistical difference of SLR and storms impacts with and without measures, however, there is 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, the average frequency of SLR and storms is ‘seldom’, while SLR average severity is ‘negligible’ and storms average severity is ‘minor’. Simultaneously, there is no significant statistical difference in SLR and storms between with and without measures on dry ports (all $p>0.05$). Also, since there are more mean values greater than 5 (never in frequency) or equal to 6 (missing data), perhaps unsurprisingly, SLR and storms have much less impact on dry ports than on seaports.

Through re-testing H1, the results are 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 is some significant difference between seaports and dry ports. Specifically, for seaports, there is 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)*; there is significant statistical difference in storms average frequency with and without measures on seaports. For dry ports, there is significant statistical difference between with and without measures in *SLR frequency d (deposition and sedimentation occurred along your port/terminal's channels)*. In other words, adaptation measures pose obvious effects in relieving storms frequency, especially in reducing land access deposition and sedimentation on seaports, and in reducing SLR frequency in deposition and sedimentation on dry ports. These different effects of measures on different types of ports might stem from the previous conclusion that SLR and storms have fewer average impacts on dry ports than seaports.

Generally speaking, ports that have adopted certain adaptation measures in the past decade would have fewer risks, but not necessarily fewer uncertainties. This is consistent with the notion that port planners and operators are usually more focused on the risks than uncertainties posed by climate change when developing adaptation measures. Simultaneously, the impacts of climate change pose little difference on seaport and dry port with respect to risks and uncertainties. In terms of SLR and storms, the impacts of SLR average severity on seaports was stronger than those on dry ports; adaptation measures do not pose obvious effects in minimizing SLR and storms: the impacts of SLR and storms are 'seldom' and 'minor' in terms of 'frequency' and 'severity of consequences'. Through further testing, we found that SLR and storms, often recognized as the primary impacts posed by climate change on ports, can only partially represent as the primary climate change impacts on seaports, while there is no obvious correlation to the risks and uncertainties posed on dry ports. Moreover, adaption measures would pose obvious effects in reliving storms frequency, especially in reducing overland access deposition and sedimentation on seaports, and in reducing SLR frequency in deposition and sedimentation on dry ports.

5. Qualitative analysis

Until now, the third and fourth research questions have yet been addressed: Q3): What are the main impacts of climate change on Canadian ports? Q4): What are the major challenges for Canadian ports to adapt to climate change impacts? The nature of these questions implies that qualitative analysis is required.

5.1. Climate change attitudes and behaviors in the past decade

Like last section, we divide climate change impacts into 'risks' and 'uncertainties' so as to elicit an overview on how climate change impacts Canadian ports. In general, respondents acknowledge a higher frequency in risks over uncertainties, except the category 'storms' that has equal number of responses. This meant that respondents realize certain (critical) climate change events. However, for uncertainties, they fail to notice (or less informed). Interestingly, instead of SLR and storms, extreme weather and high winds are 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 have became the third frequent uncertainty, however, precipitation change is a more noticeable risk rather than storms surge or SLR (Figure 1).

[INSERT FIGURE 1 ABOUT HERE]

During the survey, respondents are requested to write down their top three climate change impacts on ports. Although the answers vary among different respondents, the results share some commonalities. Unsurprisingly, extreme weather (unpredictable patterns, hot summer, polar vortex, heavy, and less or freezing rain) tops the list with 15 responses, while high winds and storm surges, and sea/water level change (e.g., rise, decrease, flooding) are the other top-listed impacts with 13 and 5 responses, respectively. To further investigate the differences between seaports and dry ports, we re-categorize the data and found that extreme weather, high winds and storm surges, and sea level change are still the top three issues. Nevertheless, high winds and storm surges most frequently happen on seaports, while extreme weather is the most frequent incident on dry ports.

5.2 Current adaptation planning for climate change

Before asking the details about adaptation plans for climate change, respondents are asked to indicate if their ports have (or will) implemented a climate adaptation plan. Only two (7.69%) said that their ports currently have an adaptation plan, most (73.08%) said that their ports have not developed an adaptation plan, but may consider it in the foreseeable future. Also, five (19.23%) said that an adaptation plan has not been developed, and would not be developed in the foreseeable future. Referring to further comments and explanation from several respondents (through in-depth interviews, see section 3), some ports have conducted certain adaptation (or protective) measures but not considered as formal climate adaptation plans. The results are consistent with previous research by Becker (2012) who found that although most port decision-makers realize the significance of climate adaptation plans, few have actually undertaken serious climate adaption planning of any kinds.

However, respondents' positive consideration for adaptation planning does lay down a foundation in assessing their attitude and behaviors about adaptation planning and measures for climate change impacts. To further acquire information on how respondents handled climate change impacts, a list containing ten possible issues is generated for their reference. As illustrated in Figure 2, the major concern of respondents (75%) falls upon the potential impacts on facility operations posed by climate change, followed by potential impacts on surrounding community and environment (45.83%), and revision of construction design standards (45.83%). Also, over half of respondents are concerned about the surrounding environment (45.83%) and air pollution/quality (20.83%). Strictly speaking, these items should be categorized as climate mitigation rather than adaptation. Whereas, aspects related to adaptation, such as the demand of new equipment and shifts in source or market location, are not given much attention.

[INSERT FIGURE 2 ABOUT HERE]

The above indicates that most considerations on climate adaptation remain on the operational level. Hence, we propose two other questions so as to analyze how ports addressed climate change impacts, and the specific adaptation/protective measures that ports have undertaken. Although results show that only few ports have developed an adaptation plan, still, it reveals that most ports have considered ways of coping with climate change impacts (Figures 3 and 4). When respondents are further asked how they would address climate change impacts on port operations, more than 70% have included the issue into respective strategic plans, and would fund it as a line item in the ports' budgets (Figure 3). This implies that climate change impacts have been already recognized as a potential threat that needed to be seriously addressed, thus gradually being integrated into ports' strategic decision-making; and indeed, some funding has been allocated too. Unfortunately, only fewer than 8% consider that climate change impacts need to be addressed through dedicated planning document(s), and this explains the lack of climate adaptation plans in most ports.

[INSERT FIGURE 3 ABOUT HERE]

After then, respondents are asked to offer details on the adaptation/protective measures in coping with climate change impacts. As most respondents come from seaports, unsurprisingly, they put priorities over ocean-related plans. As shown in Figure 4, storms response plans, drainage pumps, port lands elevation, and sea wall each occupied over 10% of the adaptation/protective measures. For dry ports, the major adaptation/protective measures are related to flooding, dredging plans, riprap, and business interruption insurance. However, considerable respondents note that they do not know, or are not confident, whether protective measures have been implemented by their respective entities/authorities, and about 20% look forward to future plans so as to replace/upgrade existing structures as a necessity.

[INSERT FIGURE 4 ABOUT HERE]

Finally, we look at the timeframe of climate adaptation planning (Figure 5). Although port's planning horizon may be project-based subject to its outcomes (Becker, 2012), most respondents consider 5-10-years, or fewer-than-5-years, as the appropriate planning timeframe. Quoting one respondent, a 5-year plan is consistent with his port's 5-year business planning cycle. The few minor exceptions range from 10-15 years to 15-20 years, and only one said that his port is preparing a 50-year plan dedicated to climate change adaptation (according to the cycle time of typical wharf facilities). As mentioned, only very limited number of ports have specific climate adaptation plans, and thus most respondents feel that it is too difficult to give a confirmed answer to this question.

[INSERT FIGURE 5 ABOUT HERE]

5.3. Climate change impacts in the future

Even though SLR and high wind or storms are not the most striking impacts, still, they pose certain risks or uncertainties on ports, especially when the respondents are mainly from seaports where high wind or storms are their top concerns. Four further questions are designed to allow them to stimulate the impacts of SLR and storms in the future that included estimating ‘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 the ‘financial cost of adaptation measure’ if adaptation will be undertaken in the future. All the data is coded from 1 to 5 in each category. Through collecting the most frequent data in every item, Figures 6, 7, 8, and 9 compare and contrast the impacts of SLR and storms with or without adaptations in the future.

[INSERT FIGURE 6 ABOUT HERE]

[INSERT FIGURE 7 ABOUT HERE]

[INSERT FIGURE 8 ABOUT HERE]

[INSERT FIGURE 9 ABOUT HERE]

First, respondents are required to estimate SLR impacts if adaptation measures would not be taken in the future (Figure 6). Since SLR is not the top concern neither for seaports nor dry ports, unsurprisingly, most respondents consider their ports to be very long (> 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, most feel negligible impacts on transport, access and costal erosion posed by SLR with the implementation of adaptation measures (*b, c, and e* in Figure 6). However, respondents expect a ‘minor’ impact on higher waves that would damage port’s facilities and ships berthed alongside, and more than ‘negligible’ impacts on deposition and sedimentation that would occur along port’s channels.

High winds and storms, as the top impacts on seaports, are estimated to have more impacts than SLR (Figure 7). In terms of the timeframe of seeing the first event happening, downtime in port operation is regarded as medium impacts (*c*), while the rest are still negligible. Excepting flood in transport infrastructure and superstructure with negligible severity and low likelihood, the three major aspects (*a, c, and d*) are expected low severity and average likelihood in the future. As Figure 7 shows, downtime in port operation due to the increase of high winds and storms (*c*) is thought to be the most striking impact with the shortest timeframe and relatively higher likelihood. Combing the results in SLR and storms, we conclude that without any adaptation measures, high winds and storms would pose greater threats on ports. This is similar to our earlier proposition on the current impacts of SLR, high winds and storm on ports.

If adaptation measures are implemented in the near future, some changes would happen on the above three perspectives, and this issue also involves the costs of adaptation planning. Figures 8 and 9 demonstrate the attitude 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, seven (out of eight) aspects are recognized to be negligible with the exception in deposition and sedimentation (*e*), when increases or expand dredging on ports, the impacts are expected to see in approximately ten years (medium) along port’s channels. Since there are most negligible severities from SLR even without adaptations, there is little difference on ports with adaptations in the future with negligible SLR impacts (Figure 8). When it is involved in likelihood, the SLR impacts are minimized to very low with adaptations competed with the average and low without adaptations. From the financial perspective, most adaptation measures are estimated to bear very low costs except the measures of ‘increase and/or expand dredging’ and ‘move facilities away from existing locations which are vulnerable to climate change risks and impacts’. Accordingly, adaptation measures would have positive effects in minimizing SLR impacts, especially in reducing SLR severity with a relatively low cost.

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 may be the greatest impacts from SLR when adaptation measures are implemented, with a shorter timeframe, stronger severity and higher likelihood then other aspects (*e* in Figure 8). By increasing and/or expanding dredging, it can significantly reduce the severity of SLR, but this requires a much higher financial commitment.

Likewise, adaptation measures would pose significant difference on the impacts of increased high winds and storms in the future (Figure 9). Through improving management in preventing effects, the severity and likelihood in downtime in port operation is reduced to ‘negligible’ and ‘very low’, respectively, although it requires 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 land access (e.g., road, railway) due to more intense/frequent storms, there are two adaptation measures (*c* and *d* in Figure 9), and both of them can reduce the likelihood to ‘negligible’. However, rather than improving the quality of land connections, diversifying land connections to port/terminal can achieve ‘very low’ costs (*d*), of which it can be regarded the most economical measure (thus also the most popular among respondents).

Overall, adaptation measures are expected to have considerable effects on minimizing the likelihood of storms’ happening, but neither having any obvious effects on extending timeframe nor on reducing severity. Moreover, when financial factors are considered, the adaptation measures in addressing high winds and storms demand significantly higher costs than those in SLR, and perhaps not surprisingly, respondents are not very keen in adopting such adaptation/protective measures. Port planners and operators still tend to adopt the most ‘economical’ measures to achieve the objective of climate adaptation, and attention on their (expected) efficiency and effectiveness remain secondary importance.

6. Discussions

For most respondents, climate change and its potential impacts are identified to be at a relatively early stage, and have considered adaptation to climate change impacts as a part of ports’ strategic planning. Indeed, most intend to develop climate adaptation plans in the near future. However, comparing with the current port’s planning horizon for addressing climate change issues, an adaptation plan usually involves a much longer time horizon. As mentioned, more than half of the respondents point out a fewer than 10 years horizon (26.92% and 30.77% for ‘less than 5 years’ and ‘5-10 years’, respectively). This confirms the ethical issue due to time dimension externalities. Similarly, some terminal operators reflect that the port authority does not inform them when the latter starts developing adaptation plans, and so that there is no coherent reference to support the former’s decision-making. As noted by Becker et al. (2012), the adaptation planning cycle should match the infrastructure lifespan, and his view is supported by a respondent, who notes that the planning horizon can be determined by the cycle time of typical wharf facility. However, most other respondents indicate that the project-based characteristics of port planning may diversify the time horizon relying on different factors (e.g., timeframe, severity, likelihood of climate change, financial cost, etc.).

Moreover, while there are still no established adaptation plans in most cases, respondents generally express interest in learning more about climate adaptation planning from counterparts. Before then, the traditional ‘port master plans’ would continue to be the main guidance for climate adaptation planning, reinforced by established regional transport, environmental, port’s land use and infrastructure plans, and various codes (e.g., Canada Building Code, Canada Fire Code, NFPA Codes, API Codes, OCIMF, ISGOTT, etc.). But this should not be deemed surprising. As our findings suggest, when trying to adopt adaptation measures, ports focus on addressing climate change 'risks' rather than 'uncertainties' (see earlier definitions of risk and uncertainty in section 1). Nevertheless, one should not forget that, with research on climate change adaptation still largely being overlooked (see section 2), many impacts posed by climate change still belong to 'uncertainty'. This raises a serious question: to what extent the adaptation measures currently adopted by ports can effectively address climate change impacts? Likely not. With the aforementioned close port-city/regional relationship, it means that port cities and surrounding regions, as it stands, are probably also not 'climate change resilient' enough.

This reinforces our earlier proposition that climate adaptation planning among ports is still strongly embedded within well-established planning systems and process, but few (if any) concrete ideas on whether these established systems and process can actually address the non-preceded climate change impacts. This indicates that the current port planning system is obsolete, and unlikely to develop effective climate adaptation plans. While most port stakeholders are aware of climate change impacts to ports' operations, and agree that some measures should be carried out, still, they remain indifferent or even skeptical on the effectiveness of the recommended strategies and solutions set out in the climate adaptation plans, especially when considering cost-benefit analysis. Most cite 'inadequate information' and 'need to know more about issue' as the major reasons (or excuses) for the slow development of any adaptation plans. While this highlights the need for more precise data collection and cost-benefit analysis, especially at the early, designing stage of adaptation planning, it confirms our proposition on the urgent need for a paradigm shift in the planning process. Planning for climate change impacts lacks precedents of any significance, and port planners often face substantial uncertainties when trying to undertake such as task. However, the current 'go it alone' system discourages port planners and operators from liaising closely with other stakeholders. This increases the difficulty to convince port stakeholders to compromise for the smooth implementation of adaptation measures, and leaves port planners and operators few options but to establish ‘economical’, incremental, but usually less controversial, adaptation measures. All these have potential ethical implications related to the space dimension externalities.

To solve this problem, it requires rigorous efforts to get port planners, operators, and other port stakeholders (both directly and indirectly involved in port operation) together, understand their views and behaviors on adaptation, and develop new norms and perspectives in climate adaptation planning. This is important because, as mentioned, port users involve different transport modes, and the existence of numerous urban, economic, and social activities within ports and port areas. As reflected by the results, with the widespread of climate change impacts and penetration of supply chains in port management, developing an adaptation plan is unlikely a simple decision that port planners and operators can ‘go it alone’, and the call for ‘external wisdom’ from other port stakeholders is not an option but necessity. As per the respondents’ feedback, terminal operators, port users, local vessel agents and the municipal governments, and specific associations involved in port activities (e.g., Canadian Shipping Association and Federation, Environment Canada) can all play key roles in adaptation planning. The difference is that their roles should move beyond ‘offering suggestions for reference’, and actively involved in ‘setting the agenda’ for ports’ adaptation to climate change impacts. With budgetary limitations and constraints in timeframe, as noted by most respondents, a new, effective mechanism should be developed to balance the benefits between all port stakeholders. Hence, close collaboration between multiple stakeholders would likely have a higher chance to develop an effective, implementable adaptation plan. Such results complement Becker (2016)’s idea on a partnership approach in climate adaptation. We argue that it is only under such a circumstance that the newly established norms would be widely accepted, adopted, and readily implemented by most (if not all) of the stakeholders.

A paradigm shift is extremely difficult to bring about in isolation due to the impacts posed by the institutional systems. Among several studied ports that have initiated some adaptation measures, the general trend is that some consultation with port stakeholders, or even the general public, have taken place. However, in most cases, it turns out afterwards that it would largely revert back within the ports when the planning process (e.g., when drafting suggested solutions in the adaptation plans) actually takes place. As discussed in section 2, most ports, and port planning, are embedded within particular institutional systems with well-established 'go it alone' practices. This creates a path-dependent mechanism which ensures that inputs from other stakeholders (i.e., those that were not interested in port activities, but not directly involved in port operations) would remain the 'for reference only' during the actual planning. It is virtually impossible for port stakeholders to accomplish this without an external agent to serve as impetus to facilitate the needed change. Further research is required on how such a new 'partnership' approach should be established so as to trigger the paradigm shift for the well being of ports' climate adaptation planning. Such a partnership approach should be designed in a way that would, in practice, encourage mutual-understandings, and potentially constructive compromises (cf. Gutmann and Thompson, 2012), between port planners and operators, port stakeholders, other transportation and supply chain sectors, leading to more effective and implementable climate adaptation plans.

7. Conclusion

Through investigating 21 seaports and dry ports in Canada, the paper analyzes the attitude and behaviors of port planners and operators when developing plans and strategies so as to adapt to climate change impacts. Effective adaptation to climate change is a key research topic in business ethics nowadays. With the pivotal roles of ports in logistics, supply chains, and international trade, together with numerous human activities taking place along waterfronts and port areas, the study offers substantial insight on the extent of business in adapting to climate change, as well as the wellness of the lives of human beings, now and the future.

The findings suggest that extreme climate (e.g., unpredictable patterns, hot summer, polar vortex, and freezing rain), high winds and storms, and sea/water level change are the major climate change impacts on Canadian ports. The stated hypotheses assist in the quantitative analysis 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. Meanwhile, it thoroughly reviews the decision-making process during adaptation planning, and highlights why and how a new paradigm should be established in port planning. It does not only improve ports' planning quality, but also dissects the dilemmas of planners and business sectors when they are asked to financially commit on some ethical issues/challenges that they may not reap the (tangible) benefits. Hence, the study serves as a perfect, illustrative reference for business from any sectors when undertaking similar decisions. Also, given the close relationship between port, city, and regions that continues until nowadays (Hall and Jacobs, 2012), it will improve urban and regional planning by offering an innovative thinking pattern for adaptation planning around the world.

Ethical concerns due to the multiple dimensions of externalities in the climate change adaptation planning of ports have been confirmed and testified by the study. On the one hand, the current planning horizon for climate change is way too shortsighted to be effective, reflecting the difficulties in addressing time-dimension externalities. On the other hand, the 'go it alone' planning system further exacerbates the space-dimension externalities, rendering port stakeholders extremely disincentivized to get involved in port climate change adaptation. Furthermore, the discrepancy between the progressive attitudes shown by the interviewees and the conservative *status quo* is an evidence for the management-dimension externalities. These ethical dilemmas are not likely to be solved by individuals. Only institutional paradigm shift is capable of bringing in real changes. The silver lining in the study is that there is no shortage of positive attitudes. Interviewees seem to be well aware of the potential benefits of effective port climate change adaptation plans towards the ports as well as the society in general, and have some willingness to act under the right context. Once a more proactive and inclusive paradigm is implemented, it should be easier to trigger motivation of action.

For the climate change impacts in the future, adaptations are 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 storm occurring. Thus, further adaptation plans call for port planners to design more effective adaptation measures and increase adaption budget limits in addressing climate change issues. A major challenge, as numerous contributors to the edited book by Ng et al. (2016a) have pointed out, is that climate adaptation planning often relies solely on incentives of port planners and operators. For instance, when the duration of the concession holders is only 20-30 years, it hardly offers any incentive for terminal operators (especially private ones) to financially commit heavily on such an ethical issue but with tangible benefits often found wanting (or most likely to be enjoyed by someone else in the distant future). In particular, in what portions does a corporate planner distribute the investment between the short-term and long-term under a limited budget? Thus, we call for cross-departmental 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 municipal governments to prioritize adaptation strategies in planning, policy making and implementation. Again, we call for the development of a new approach in triggering paradigm shift in ports' adaptation planning process.

Last but not least, despite certain limitations during the research (e.g., inaccessibility to some respondents located in highly remote areas), we believe that the study approach and findings serve as a very solid foundation for future researchers in any business and planning disciplines to investigate the appropriate ways in developing adaptation and resilience. Further research is required to further investigate this increasingly important issue, notably the appropriate approach in developing an effective framework in developing effective climate adaptation plans.

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