PORT DECISION-MAKER PERCEPTIONS ON THE EFFECTIVENESS OF CLIMATE ADAPTATION ACTIONS

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Abstract

Effective adaptation to climate change impacts is fast becoming an important research topic nowadays. Hitherto, the perceptions and attitudes of stakeholders on climate adaptation actions are understudied, partly due to the emphasis on physical and engineering aspects during the adaptation planning process. Understanding such, the paper explores the perceptions of port decision-makers on the effectiveness of climate adaptation actions. The findings suggest that while port decision-makers are aware of potential climate change impacts and feel that more adaptation actions should be undertaken, they are sceptical about their effectiveness and value. This is complemented by a regional analysis on the results, suggesting that more tailor-made adaptation measures suited to local circumstances should be developed. The study illustrates the complexity of climate adaptation planning and of involving port decision-makers under the current planning paradigm.

Keywords: Climate change, adaption, port, perception, survey

1. Introduction

Climate change has become an important issue for both the research community and people's daily lives. "Climate change impacts include multi-hazard phenomena, such as the simultaneous occurrence of sudden-onset hazards and creeping changes" (Birkman et al. 2010, p. 188). The effects can be multifaceted, where changes in weather patterns directly affect the Earth's flora, which in turn impacts humans and animals. Among all the effects associated with climate change, sea level rise (SLR) and catastrophic storms are of particular concern when it comes to maritime logistics. As a result of the geographical features of their business, ports are more vulnerable to some aspects of climate change, compared with other logistics stakeholders (e.g., shipping lines, inland carriers) that can more easily make logistics shifts to avoid the issues associated with storms or flooding. In this case, a "port stakeholder" is understood as a person or organization that is involved and/or interested in the operation, planning, development, management, and/or governance of a port. They include port authorities, port operators, managers, employees, customers, community members, shipping agencies, environmental groups and government agencies. Due to the high concentration of infrastructure and sensitive value at ports, the potential damage caused by climate change can significantly affect the whole supply chain (Osthorst and Mänz 2012, p. 227). Through an initiative by 55 of the world's key ports, climate change was made a priority in addressing threats posed to ports. After adopting the World Ports Climate Declaration (WPCD), they designed the World Ports Climate Initiative (WPCI) to address the problems posed by climate change. One such problem regards the manner in which institutions operate when managing climate change related issues. The following are required to extensively address them, including 1) an extensive collaboration among the main port cities and key stakeholders in shipping and 2) a broader approach to integrate as many issues as possible, compared to the current specified approach (Fenton, 2017).

Maritime transport moves more than 80% of global cargoes and significantly influences the world's economy (Ng and Liu 2014). Ports play pivotal roles in supply chains, as they connect ocean logistics with inland transport, which in turn drives the growth of regional and national economies. Given that ports are the interface where goods are traded across boundaries, climate change may cause significant economic losses to ports, influencing the regional economy, the operation of supply chains and the lives of people in coastal cities. In particular, ports and the surrounding regions could pay a high price for climate change impacts, from the breakdown of day-to-day operations to infrastructure damage (and repairs) (Becker et al. 2016). Facing such risk, ports must take effective actions to ensure smooth operations and provide a quality service (Ng et al., 2016).

It is noted that climate change adaptation is different from mitigation and the strategies for dealing with them are not necessarily similar. Becker et al. (2012) refer to mitigation for ports as ways that port operations may moderate climate change through reducing their own greenhouse emissions (e.g., by requiring ships to use shore power or changing from diesel to electric power for vehicles on the port), and the development of other ‘green ports’ practices (see Zhang et al. 2016). By taking such actions, ports may also benefit from gaining a better public image and enhancing local air quality by reducing particulates. However, “greening the port” does not necessarily address the need to adapt to climate change impacts (Knatz 2016). As mitigation can take centuries to yield results (Füssel and Klein 2006), it is crucial to undertake adaptation measures to respond effectively to climate change impacts in the nearer term. Adaptation refers to how a port might take measures to build resilience against the impacts posed by climate change. Although some scholars have addressed ports’ adaptation to climate change from various aspects - economic, policy, risk and so on (see Ng et al. (2013) for a detailed discussion), more attention has generally been paid to mitigation (Araral 2013; Ekstrom and Moser 2013; Ng et al. forthcoming(b)).

Some port decision-makers hesitate to engage in adapting to this new threat and prefer to gain more information and knowledge instead of making proactive investments (Zhang et al., 2017). There are many reasons why a port may wish to defer investment, especially when it comes to the protection against low-probability, high-impact, events such as tropical storms. Also, SLR is difficult to plan for, as the effects are incremental and the rate of rise remains uncertain. The “wait and see” approach raises the question: To what extent is it necessary or important for ports to plan and invest to adapt to climate change in the near future? Understanding such, this paper 1) provides an overview of perceptions and attitudes that port decision-makers currently hold towards climate adaptation actions; 2) offers strategic directions for future planning efforts; and 3) calls for more attention from scholars and practitioners to ports’ climate adaptation. Though also important, the issue of management and governance is not addressed, as it is beyond the scope of this study[1].

The rest of the paper is structured as follows. Section 2 outlines the theoretical background, research framework, and methodology, followed by the statistical analysis of the collected data, including hypothesis testing, in section 3. Section 4 discusses the analytical results. Finally, the conclusion can be found in Section 5.

2. Theoretical Background, Research Framework and Methodology

Becker et al. (2012) undertook a global survey on climate change adaptation and found that port operators were concerned about climate change impacts but had not yet taken any concrete steps toward adaptation. They also found that respondents felt that relevant authorities had not gone far enough to educate port decision-makers about climate risks. Further, they were of the opinion that SLR was not an immediate concern, as the consequences were too far into the future. Among respondents, little had yet been done to prepare for the consequences of climate change. Engineers did not typically incorporate climate change in their designs. Similar to

[1] See Ng et al. (forthcoming(a)) and Zhang et al. (2017) for detailed discussions on climate adaptation management and governance.

Becker et al. (2012), a survey on US ports was conducted by Bierling and Lorented (2008) and found that climate change would pose negative influences to port business, but adaptation planning was scarcely undertaken at that time. Similar works by CSLC (2009) and Moser and Tribbia (2006) offered similar conclusions, in which port decision-makers were aware of climate change impacts but were not yet responding through planning.

In this regard, Ng et al. (forthcoming (b)) pointed out that further studies are needed to investigate whether the currently proposed adaptation measures, like the 'international best practices' (IBPs) proposed by inter-governmental organizations (e.g., UNCTAD), are really able to tackle such impacts effectively. Given that IBPs are recognized as important steps to develop adaptation plans, they argued that regional analysis (to identify diversifications among different regions) was particularly crucial for port decision-makers to appropriately adopt this method when initiating such plans. Moreover, given the recent experiences from major hurricanes, such as Katrina, Sandy, and Harvey in 2005, 2012, and 2017, respectively, the attitudes towards climate change adaptation might have changed. Based on such, we propose two hypotheses, as follows:

H_1: If there are no adaptation measures undertaken in the near future, port decision-makers perceive that SLR and strong storms due to climate change will have a more serious impact on ports.

H_2: Port decision-makers perceive that adaptation measures based on IBPs would be effective in enhancing the resilience of port facilities and infrastructure to SLR and strong storms.

Figure 1 provides an overview of the research framework. The online survey distributed was divided into three sections. In the first section, existing risks and impacts due to climate change are identified. In the second section, adaptation measures that have been taken in ports are discussed. Finally, two different scenarios (one with and one without adaption measures in the future) are presented.

[INSERT FIGURE 1 ABOUT HERE]

To facilitate the study process, an exploratory survey was designed. As adaptation is still a relatively new research topic, limited data is available. Therefore, an online survey enabled a broad range of issues to be explored with relatively easy responses from managers operating different ports around the world.

2.1 Targeted ports, sampling, and respondents

A study by Nicholls et al. (2008) demonstrated that, by 2005, the top ten port cities with populations exposed to climate change were located in both developed and developing nations. Thus, this paper targeted ports (coastal ports) in both developed and developing countries.

Through e-mails and direct mails, we reached out to 132 ports located in five continents between the fall of 2014 and early 2016. The snowball sampling technique started with contacting the port management and respondents were then invited to recommend other potential ports (and their decision-makers) to participate in the survey. Port decision-makers in this study refer to individuals and organisations responsible for taking actions on issues with regard to the management of a particular port. The targeted respondents were typically presidents, directors of strategy and business development, engineers, environmental managers, and so forth. It is noted that the responders to the survey filled it without filling in the space for the title (position held in the organization), even though it was provided. No particular reason is attributed for this.

To enhance valid responses, the Dillman total design survey method was employed (Hoddinott and Bass 1986). For those that did not respond, a second mail of survey links and a cover letter were sent approximately one month after the initial mailing. By doing so, the number of incomplete questionnaires was kept to a minimum. By mid-2016, we received 82 replies. After a screening process, 67 responses were deemed satisfactory to proceed with the analysis. The distribution of responses of ports from different continents can be found in Table 1. Nearly 80% of the valid responses come from Asian and North American ports, thus creating an ideal platform for a comparative analysis between the two regions (to be illustrated in section 3.3).

[INSERT TABLE 1 ABOUT HERE]

2.2 Questionnaire design and data processing

There are broad ranges of factors responsible for the impacts climate change pose to ports. It is impossible to address all of them in a single study. As per Becker et al. (2012), Ng et al. (forthcoming(b)), and other relevant previous research (see earlier), we selected SLR and storms (including high winds) as the factors for this study. Also, in order to test port decision-makers' attitude to IBPs, the environmental drivers of climate change and their potential threats were developed with strong reference to the IBPs established during the *Ad Hoc* Expert Meetings organized by UNCTAD in 2011 (cf. UNCTAD, 2012).

The questionnaire (Appendix A) was designed to test the stated hypotheses. The first independent variable (IV) is time, categorized as binary: in the past five years or the predicted future. As the aim is to identify the differences between how respondents anticipate climate impacts without adaptation interventions, it is assumed there are no future adaptation measures. The dependent variable (DV) is the severity of each potential climate change impact, as perceived by respondents.

For the second hypothesis, IV is a categorical variable, which represents whether or not future adaptation measures will be taken at the port. DV is the level of climate change impacts anticipated by respondents. Adaptation plans are the corresponding measures (or planned measures) to each of the selected impacts. The measurement of DV contains three risk parameters:

(1) timeframe (when you expect to see the impact of climate change for the first time);

(2) severity of consequences;

(3) likelihood (that the event will occur) (Yang et al., forthcoming).

The questionnaire consists of three scenarios: (1) the present situation; (2) the future (in the coming decade) without developing any adaptation measures; and (3) the future with adaptation measures being developed. The present situation includes the climate-related impacts decision-makers have experienced in their role as professionals in the port industry; thus, it has a significant influence on perceptions. The two different scenarios in the future reflect their knowledge of climate change risks and expectations. The response to each question is arranged on a Likert scale.

After the data collection process, the sign test was used as a pair-wise comparison to compare two groups of variables (McCrum-Gardner 2008), before and after treatment. Statistical software Stata 12 was used to conduct the sign test. All responses "I do not know/I am not sure" were excluded, which is an accepted way of dealing with missing ordinal data (Heir and Weisæth 2006).

3. Results

3.1 Statistical analysis

3.1.1 Existing risks and impacts due to climate change

To measure the climate change impacts experienced at respondents' ports between 2010 and 2015, "frequency" and "severity of consequences" were utilized. Each of the parameters was scaled to five levels (1-5). In general, more than half of the respondents agreed that SLR impacts did not happen or only happened once over the past five years. Among the five SLR impacts (Figure 2), deposition and sedimentation along port/terminal's channels appeared to be the most common, with 61% of the respondents (41 out of 67) reported that it had happened at least once, followed by coastal erosion at or adjacent to the port/terminal (51%, 34 out of 67). In terms of frequency, respondents indicated that transport infra- and superstructures and utilities were the most unlikely to be damaged by SLR, as only 33% reported that this impact has taken place at least once. In "I don't know/I'm not sure", approximately 10% had no knowledge of the SLR impact frequency. This could be attributed to the fact that no records exist or that they are simply unaware of them.

[INSERT FIGURE 2 ABOUT HERE]

Regarding the severity of consequences, respondents reported that the most serious impact of SLR to ports was deposition and sedimentation (Figure 3), with 46% reporting that SLR resulted in minor damages to ports. Damage caused by SLR to transport infra- and superstructures had the least impact, with 31 respondents selecting "negligible". Similarly, with the frequency section, transport infra- and super-structures and utilities were the least likely to be damaged. Approximately 25% said that they did not have any or had very limited knowledge of the severity of consequences of climate change on ports. The percentage of "I don't know/I'm not sure" was second only to the negligible level. Overall, deposition and sedimentation were thought to be the most serious impacts caused by SLR on ports.

[INSERT TABLE 3 ABOUT HERE]

47 respondents (70%) said that there had been downtime at least once in the past five years, making it the most prevalent of the four high winds and storms' impacts (Figure 4). Almost half of the respondents indicated that the other three impacts had taken place at least once (52% for waves, 51% for damaged transport infra- and superstructures and utilities, and 52% for limited overland access). Compared to SLR, respondents clearly have a better knowledge of impacts (less than 10%) caused by high winds and/or storms regarding frequency.

[INSERT FIGURE 4 ABOUT HERE]

Also, "ports shutting down" was one of the most prevalent impacts noted: 57% of the respondents reported that high winds and/or storms had at least caused "minor" loss to their ports. Approximately 18% had "no idea" about the severity of the consequences (lower than that of SLR (25%)). The port decision-makers had more knowledge of impacts caused by high winds and/or storms than those brought by SLR. Their understanding of factors related to frequency were better than those for consequences.

3.1.2 Recent adaptation measures to climate change risks

In response to how ports addressed climate change risk, the perceptions of respondents varied substantially. 33% claimed, “climate change risks had not been addressed,” while 25% indicated “climate change had been addressed as part of port’s design guidelines or standards.” Other adaptation strategies and actions included “having a specific climate change planning document” (21%), “having climate change strategies and actions included in the port/terminal’s budget” (13%), and “having climate change specifically addressed in the port’s port/terminal insurance” (Figure 6). This suggests that, thus far, adaptation strategies and actions have only minimally been addressed at the respondents’ ports.

[INSERT FIGURE 6 ABOUT HERE]

In terms of specific protective measures that could be implemented to reduce climate risks (Figure 7), ports/terminal authorities were aware of protection measures available at the ports, such as breakwaters (33%), storm response plan (28%), storm insurance (24%), and protective dikes (24%). 33% of the respondents planned to replace/upgrade existing structures. This suggested that ports decision-makers had been implementing strategies and actions based on issues and concerns specific to their needs but not addressing the problem holistically. However, 15% indicated that they were not aware of any protective measures implemented at their ports.

[INSERT FIGURE 7 ABOUT HERE]

3.2 Hypothesis testing

A sign test was applied to test H_1. An example of the output can be found in Figure 8. The two-sided test examined the difference between two pairs of observations and the results were neutral indicators. The *p*-value of the two-sided test in Figure 8 is 0, less than 0.05; therefore, the null hypothesis (H_0) was rejected, accepting the alternative one. That is to say, the severity of consequences of higher waves caused by SLR was significantly different between the past five years and the future without adaptation. The one-sided test provided indicators of positive and negative results. The *p*-value of the “negative” test was 0, under the significance level, thus suggesting that the impacts of higher waves could be caused by climate change that could cause greater losses in the future. The *p*-values of all the two-sided tests and “negative” one-sided tests are less than 0.05, indicating that, regardless of SLR or high winds and storms, port decision-makers believed that such risks would pose more serious loss to ports. Thus, H_1 is accepted.

The same method was adopted to test H_2. An example can be found in Figure 9. The sign test was conducted 21 times regarding SLR, as seven adaptation measures were designed to address five impacts and each adaptation measure had three parameters (timeframe, severity of consequence, and likelihood). Each sign test outputs three *p*-values, two for the one-sided tests and the third one for the two-sided test. However, only six out of the 63 statistical indicators are less than 0.05. Except for one *p*-value from a two-sided test which indicated a neutral result, the other five significant results are from “slr_c_prob”, “slr_d_time”, “slr_d_soc”, “slr_d_prob”, and “slr_e_2_prob”. Interestingly, all the five one-sided tests provided “negative” results. The inference from the *p*-value of “slr_d_time” suggested that deposition and sedimentation caused by SLR would occur sooner if no adaptation measures are implemented in the future. On the contrary, the remaining four statistically significant results indicate that impacts can be even worse with adaptation measures in the future.

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

[INSERT TABLE 4 ABOUT HERE]

All of the significant results fell into "timeframe". The significant *p*-values of the "negative" one-sided tests indicated that adaptation measures would effectively postpone the first occurrence of their associated climate change impacts. Thus, we can conclude that there is no real consensus regarding the benefits of adapting to climate change. In general, respondents believe that adaptation measures 1) have no effect, 2) have positive effects, and even 3) have negative effects. Hence, H_2 is not fully validated.

3.2.2 Verification of hypothesis testing

The Friedman test (see an example in Figure 10) was conducted to verify the results of the hypothesis testing, a non-parametric test to examine the difference among multiple groups (cf. Sheldon et al. 1996). Taking the consistency of the three scenarios (the past, the future without adaptation and the future with adaptation) into consideration, the severity of consequence was selected as the tested variable. The *p*-values were less than 5%, therefore, the null hypothesis for the three groups of data from the same distribution was rejected. Consequently, the results of the Friedman test suggested that the impacts posed by climate change on the three scenarios were significantly different.

In addition, the Wilcoxon signed-rank test (see an example in Figure 11) was conducted to determine the relationships between each of the two groups. The significance level was adjusted to 0.017 based on the rule of Bonferroni correction. The results show that, there was a significant difference between the past and the future without adaptation measures. Conversely, an apparent benefit of adaptation measures in the consequence of climate change impacts in the future ($p \geqslant 0.017$) could not be identified. Taken together, the results suggest that the findings of the above hypothesis testing were robust.

3.3 Regional analysis

3.3.1 Knowledge about climate change impacts

As mentioned before, data of Asia (n=39) and North America (n=14), the two largest portions of the valid responses, were tested to examine the regional difference in perceptions of port decision-makers, as illustrated in Figure 12. Respondents from North America reported low in the three variables (frequency and severity of consequence of impacts caused by SLR, as well as frequency of impacts posed by high winds and/ or storms). Interestingly, Asian respondents were more concerned with high winds/storm- related impacts than the effects posed by SLR. North American respondents did not have such tendency.

Turning to the results regarding the two parameters, percentages in frequency were lower than in severity of consequence, no matter which climate change risk. It is apparent that respondents found it more challenging to estimate the effects of climate change.

[INSERT FIGURE 12 ABOUT HERE]

The results of knowledge level regarding SLR are revealing in several ways (Figure 13). First, there was clearly more knowledge of frequency than the severity of consequence of SLR. Second, except for the consequence of "limited overland access" caused by SLR, respondents from North America indicated that they had more knowledge of the potential impacts posed by

SLR than their Asian counterparts did. “Limited overland access” refers to the exposure of limited land remaining in a particular area after consequences of non-adaptation of climate change are experienced, e.g. SLR. In this case, North American respondents from the ports used for the study tended to be the most experienced with the impacts of coastal erosion, whereas Asian respondents had less experience with this impact[2]. Interestingly, “limited overland access” - the impact with the largest percentage among North American respondents, was the most familiar impact to Asian respondents.

[INSERT FIGURE 13 ABOUT HERE]

Figure 14 revealed that respondents had better knowledge regarding the frequency of the impacts posed by high winds and/or storms than their consequences. North American respondents had better knowledge of these potential climate change impacts. They were more familiar with the impacts of “higher waves”, “damaged transport infra- and superstructures and utilities” and “downtime”, whereas Asian respondents were more knowledgeable on the impacts of “limited overland access”. In this case, the major difference between these two sets of respondents fell into “damaged transport infra- and superstructure and utilities”. They reported similar perceptions about the impact of “downtime”. However, a significant gap of perceived risk with regards to limited overland access” impact was detected for North American respondents.

[INSERT FIGURE 14 ABOUT HERE]

3.3.2 Effectiveness of adaptation measures

Further statistical tests were performed to determine whether respondents felt that potential adaptation measures would be effective. The sign test was conducted to examine the difference between data from Asian and North American respondents. Adaptation measures were not expected to affect the impacts of SLR in the foreseeable future (at least next five years). The measures, even if implemented, may take a while before the impacts are experienced. Interestingly, the severity of the consequences of “higher waves” and “limited overland access” was reported to be even more serious with adaptation measures. One benefit of adaptation measures that was identified could be the increase in resilience to the impacts of high winds and/or storms. However, no significant differences were found between the future scenarios with and without adaptation regarding the severity of consequence and likelihood of climate change impacts.

The results among North American ports did not show any significant differences between the future scenarios with and without SLR adaptation measures. Similarly, only two *p*-values (of the 45 indicators) were below the significance level, suggesting that respondents perceived that adaptation measures would be beneficial to mediate the impacts posed by high winds and/or storms. They believed that new or extended breakwaters would effectively decrease the probability of damage associated with higher waves. The measure “improvement in management to prevent effects” was expected to postpone the timeframe of the first observation of port downtime due to higher winds and/or storms.

4. Discussion

An obvious finding about the “past scenario” was that the respondents were more knowledgeable on frequency than consequence. One explanation is the lack of robust

[2] This may due to the fact that the erosion problem is less prominent in Asia. This is subject to further research.

methodologies that would enable respondents to measure and calculate the consequences of climate change impacts at their ports. This barrier to assessing future scenarios is also endorsed through the arguments by Moss et al. (2010).

Also, our findings confirm that port decision-makers perceive that the impacts posed by SLR and high winds and storms will become more serious (hence, accepting H_1). This calls for more approaches to adapt to climate change impacts. However, our attempt in confirming H_2 registered negligible responses for SLR (only 1 from 63). There was a similar observation for the severity of consequences and likelihood of high winds and storms. In fact, respondents even doubt, or have an indifferent attitude on, the effectiveness of adaptation actions. A possible explanation is that they believe that adaptation measures would not be implemented, or that they have few concrete ideas on what to do even if they are aware about how climate change could impact ports. Considering the current measures, as well as the high proportion of respondents answering "I do not know/I am not sure", it is likely that without sufficient reliable information, port decision-makers may struggle to build port resilience.

4.1. Doing something (anything) is better than doing nothing

It is also possible that port decision-makers are not too concerned about the effectiveness of adaptation actions. Instead of voluntary engagement to protect their own long-term interests, they just feel obliged to engage. It is similar to the classical 'goalkeeper's dilemma' where they make movements to show that any (possibly sub-optimal) effort has been made, rather than being later blamed for doing nothing. Port decision-makers may feel a similar situation: they need to undertake adaptation actions to show accomplishments. Rather than treating adaptation as a "day-to-day" commitment, they treat it as a "political duty" and opportunity to showcase, regardless of the ultimate effectiveness of the adaptation investment[3].

4.2 Those with more knowledge have more faith in adaptation solutions

Further analysis of Asian respondents reveals the relationship between perceptions of risk and perceptions around climate adaptation actions. If climate change increased the ports' exposure to storms, Asian respondents felt that effective adaptation measures would postpone the climate change related impacts of such storms. However, they demonstrated a perception of less risk of SLR. By enhancing the understanding of climate change effects, port decision-makers may be more supportive of making adaptation investments. However, such a link with understanding the consequences of climate change investment was not identified among North American respondents. This suggests that the relationship between climate change knowledge and perceptions around the effectiveness of adaptation needs further research.

It seems that port decision-makers lack understanding of the consequences associated with non-adaptation of ports to climate change impacts. Results for all the parameters show some significant, comprehensive and dispersed outcome. Nevertheless, significant *p*-values only fall in the parameter of timeframe in terms of high winds and storms. Further, all the *p*-values in "timeframe" are significant. This may be related to the development of storm and high winds. Respondents may be more confident in doing a projection of an event rather than evaluating its consequences. However, more than 50% of the respondents are from Asia (Table 1) where many ports suffer yearly the effects of severe storms. Thus, they are likely to possess more reliable data and hence a better perception of the risks. This implies that experience with

[3] It should be noted that, the statement is the view point of the authors on the potential rationale for decision-makers.

potential consequence of climate change is an important element in port's adaptation planning. In this case, no significant *p*-values in adaptation measures in high winds and storms were found among North American ports, whereas the adaptation measures were detected to be effective regarding such an event among Asian ports.

Furthermore, respondents from different regions possess different levels of perception regarding impacts. Among the impacts posed by SLR, for example, Asian respondents were the most knowledgeable with "limited overland access", while the North American respondents tended to possess the least perception of risk. This shows that local situations must be taken into account in adaptation planning, since knowledge is highly dependent on experience of past events. While IBPs may be effective for the development of some adaptation plans, they may be less effective in implementation of resilience actions. This can be deduced from our results. Also, the different results of SLR and high winds and storms raise another potential problem for adaptation planning.

4.3 IBPs May Not Be Appropriate

Some port decision-makers responded that their port situation might even be better without undertaking any adaptation measures at all. As the adaptation measures in our questionnaire were developed based on the IBPs of UNCTAD (UNCTAD, 2012), this study also serves as a test on the attitudes of port decision-makers on such IBPs. According to Scott et al. (2013), the IBPs available for the Terminal Maritimo Muelles el Bosque Cartenga in Columbia are related to the infrastructure, engineering works and design. Examples include paving the port, drainage improvements, causeway road design, and incorporating the consequences of climate change in insurance premiums. For sure, policymakers and port decision-makers sometimes desire IBPs for guidance due to insufficient knowledge and experience (e.g., UNCTAD helped Jamaican and St. Lucian policymakers in adaptation planning in 2016). However, while subject to future research, our findings suggest that the payoff from such an IBP approach may, in practice, be too "distant" for port decision-makers to appreciate their value, at least in the short term. One should be more cautious on the roles of IBPs in climate adaptation planning.

4.4 Lack of incentives for adaptation

Another finding from our study concerns port decision-makers' attitudes towards adaptation measures. Even with the availability of adaptation plans and programs, they often prefer not to implement them, as they are too costly in terms of money, time, or human resources. A good example was the port of San Diego (PSD), where its port authority suspended the adaptation component of its *Climate Mitigation and Adaptation Plan* (CMAP) a year after it was publicized in 2013. The reason for the suspension is still not totally clear but according to Messner et al. (2016), the lack of focus and understanding and the low level of urgency amongst stakeholders are key factors. This is further made worse by the uncertainties surrounding the implementation of the plan. The current planning paradigm in adaptation is often initiated, and drafted, by the port authority based on experiences from climate change mitigation, especially the "top-down" approach in controlling/achieving CO_2 emission targets/milestones. This often results in the (excessive) "merging" of climate adaptation and mitigation strategies and measures (e.g., PSD's CMAP). Understanding such, a paradigm shift from "go it alone" (largely based on the port authority) to a more "collaborative" approach is necessary. Such a view is also echoed by Becker et al. (2018). Though CMAP is yet to be implemented, it is a blueprint for the best way forward to addressing the problem of ports' adaptation to climate change.

5. Conclusion

The paper explores port decision-makers' perceptions on the effectiveness of climate adaptation actions. In general, port decision-makers have better risk perceptions of the impacts caused by high winds and/or storms than those produced by SLR. Moreover, their perception about frequency is clearer than those about the severity of consequences of factors related to climate change. In addition, port decision-makers anticipate, compared with the past five years both SLR and storms and high winds, that climate change will result in more serious impacts in the next decade. However, some respondents doubt the effectiveness of adaptation measures, especially IBPs. Ports' adaptation plans and implementations are unsystematic and the adaptation work is still at the embryonic stage. Furthermore, the "regional diversification" of climate change impacts is examined as a critical element in port adaptation planning. It is consequently pivotal to tailor-made adaptation methods in accordance with a specific climate change risk.

On account of the complexity of climate change problems, a paradigm shift in adaptation planning approach is imperative and collaborative work with all the stakeholders involved is required. Adaptation to climate change is a complex and diverse issue. As pointed out by UNCTAD (2012), ports should not expect the problem to be solved only through individual efforts. Other port stakeholders (e.g., terminal operators, shipping lines, real estate developers, yacht clubs, and all other parties using port lands) and external stakeholders (e.g., the local community, scholars, etc.) should work together in a collaborative way. With the rise of port-focal logistics (Ng and Liu 2014; Martín-Alcalde et al. 2016) where ports become even more integrated into global supply chains, a paradigm shift in adaptation planning is not an option but a necessity.

A significant finding in our study is that port decision-makers forecast climate change impacts to increase at their ports. Respondents are aware that appropriate adaptation actions should be undertaken to enhance resilience. Furthermore, it suggests that investing in adaptation measures may not translate into immediate gains. Also, it shows that adaptation planning to climate change is a complex exercise and port decision-makers' have doubts about the effectiveness of the outputs. An extensive exposure to knowledge on the consequence of non-adaptation to climate change would be helpful to port decision-makers to understand what they may lose when nothing is done. However, it should be noted that the issue of management and governance is not addressed in the survey and is thus mainly from the authors' own thoughts on the potential reasons for some of the stated observations. Moreover, to our best of knowledge, this is a pioneer study reporting regional diversification in climate change adaptation. Admittedly, our survey (and thus results) is heavily weighted towards Asia and North America. Thus, more research is required to further verify our findings and conclusions. In this case, more investigations on ports located in the Southern Hemisphere will be especially useful.

Last but not least, the paper is a pioneering attempt in dissecting a critical issue that urgently requires more understanding. It does not only illustrate the indifferent attitudes of ports to develop adaptation measures but highlights the necessity of a paradigm shift in the adaptation planning approach. We believe that the study constructs an ideal platform for further research and helps port decision-makers to develop effective adaptation solutions and guidelines to ensure that ports will become more resilient in the future.

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Table 1

Geographical distribution of valid responses.

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

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

Table 2

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

ADAPTATION	**PARAMETER**	**POSITIVE_ONE SIDED**	**NEGATIVE_ONE SIDED**	**DIFFERENT_TWO SIDED**
	slr_a_time	0.7878	0.345	0.69
slr_a	slr_a_soc	0.9552	0.0877	0.1755
	slr_a_prob	0.7566	0.3642	0.7283
	slr_b$_1$_time	0.779	0.3506	0.7011
slr_b$_1$	slr_b$_1$_soc	0.779	0.3506	0.7011
	slr_b$_1$_prob	0.655	0.5	1
	slr_b$_2$_time	0.9449	0.1077	0.2153
slr_b$_2$	slr_b$_2$_soc	0.7709	0.3555	0.7111
	slr_b$_2$_prob	0.5	0.655	1
	slr_c_time	0.8761	0.221	0.4421
slr_c	slr_c_soc	0.9599	0.0814	0.1628
	slr_c_prob	0.9947	**0.0173**	**0.0347**
	slr_d_time	0.9853	**0.0354**	0.0708
slr_d	slr_d_soc	0.9904	**0.0261**	0.0522
	slr_d_prob	0.9825	**0.0401**	0.0801
	slr_e$_1$_time	0.8275	0.2858	0.5716
slr_e$_1$	slr_e$_1$_soc	0.8852	0.2122	0.4244
	slr_e$_1$_prob	0.5806	0.5806	1
	slr_e$_2$_time	0.8595	0.2366	0.4731
slr_e$_2$	slr_e$_2$_soc	0.9786	**0.0494**	0.0987
	slr_e$_2$_prob	0.655	0.5	1

Note: 1) A/b/c/d/e from slr_a/b/c/d/e is the impact caused SLR. 2) A/b$_1$/b$_2$/c/d/e$_1$/e$_2$ from slr_ a/b$_1$/b$_2$/c/d/e$_1$/e$_2$_time/soc/prob is the specific adaptation measure. A is to build new breakwaters and/or increase their dimensions; b$_1$ is to improve transport infra- and superstructures resilience to flooding; b$_2$ is to elevate port land; c is to protect coastline and increase beach nourishment programs; d is to increase and/or expand dredging; e$_1$ is to improve quality of land connections to port/terminal; e$_2$ is to diversify land connections to port/terminal. 3) Prob, time, soc are likelihood, timeframe, and severity of consequence, respectively.

Table 3

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

ADAPTATION	PARAMETER	POSITIVE_ONE SIDED	NEGATIVE_ONE SIDED	DIFFERENT_TWO SIDED
hw_a	hw_a_time	0.9962	**0.01**	**0.0201**
	hw_a_soc	0.8192	0.2923	0.5847
	hw_a_prob	0.1808	0.8998	0.3616
hw_b	hw_b_time	0.9996	**0.0017**	**0.0033**
	hw_b_soc	0.9622	0.0843	0.1686
	hw_b_prob	0.5775	0.5775	1
hw_c	hw_c_time	0.9993	**0.0022**	**0.0043**
	hw_c_soc	0.9461	0.1148	0.2295
	hw_c_prob	0.1002	0.9506	0.2005
hw_d$_1$	hw_d$_1$_time	0.9999	**0.0005**	**0.0009**
	hw_d$_1$_soc	0.9646	0.0748	0.1496
	hw_d$_1$_prob	0.1725	0.9075	0.3449
hw_d$_2$	hw_d$_2$_time	1	**0.0001**	**0.0003**
	hw_d$_2$_soc	0.8998	0.1808	0.3616
	hw_d$_2$_prob	0.221	0.8761	0.4421

Note: 1) HW stands for high winds and storms. 2) A/b/c/d from hw_a/b/c/d is the impact caused high winds and storms. 3) A/b/c/d$_1$/d$_2$ from hw_ a/b/c/d$_1$/d$_2$_time/soc/prob is the specific adaptation measure. A is to build new breakwaters and/or increase their dimensions; b is to improve transport infra- and superstructures resilience to flooding; c is to improve management to prevent effects; d$_1$ is to improve quality of land connections to port/terminal; d$_2$ is to diversify land connections to port/terminal. 4) Prob, time, soc present likelihood, timeframe, and severity of consequence, respectively.

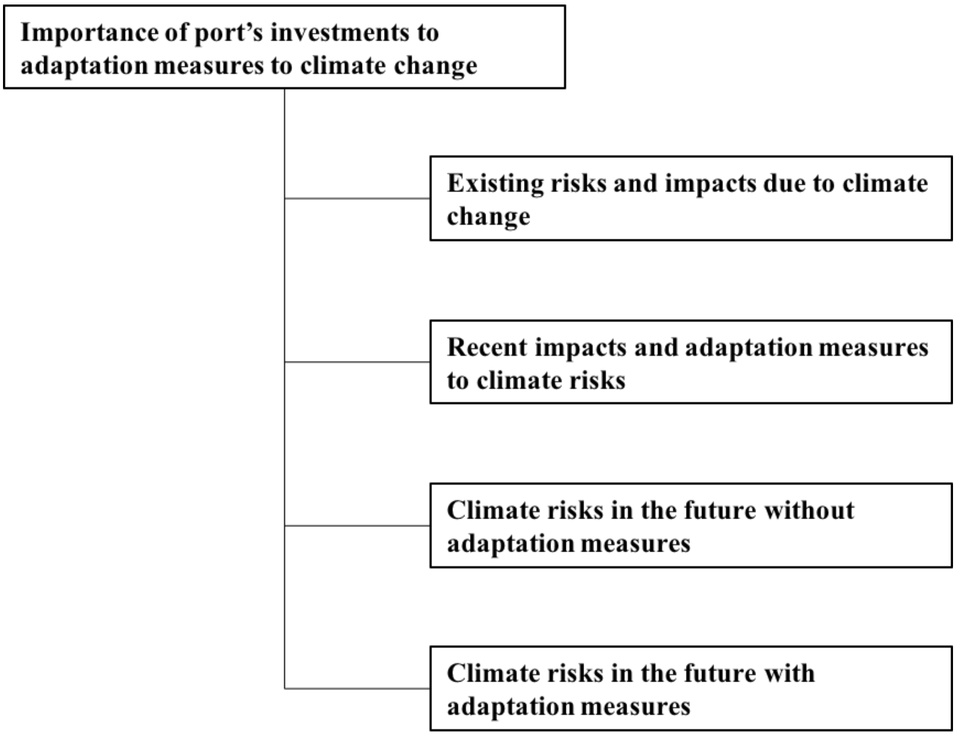

Fig. 1. Research framework. *Source*: authors.

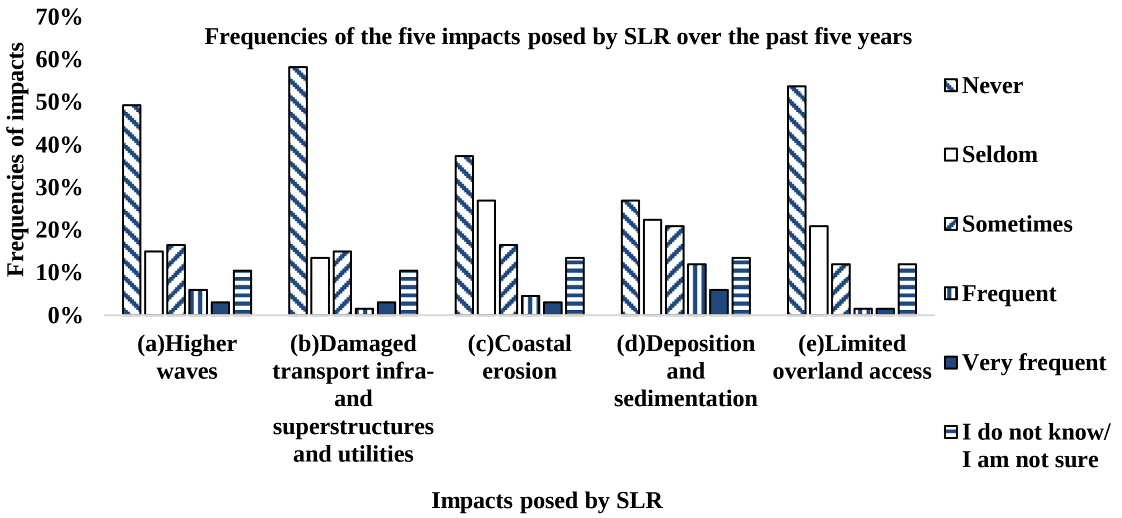

Fig. 2. Participants reporting different frequencies of the five impacts posed by SLR over the past five years.

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

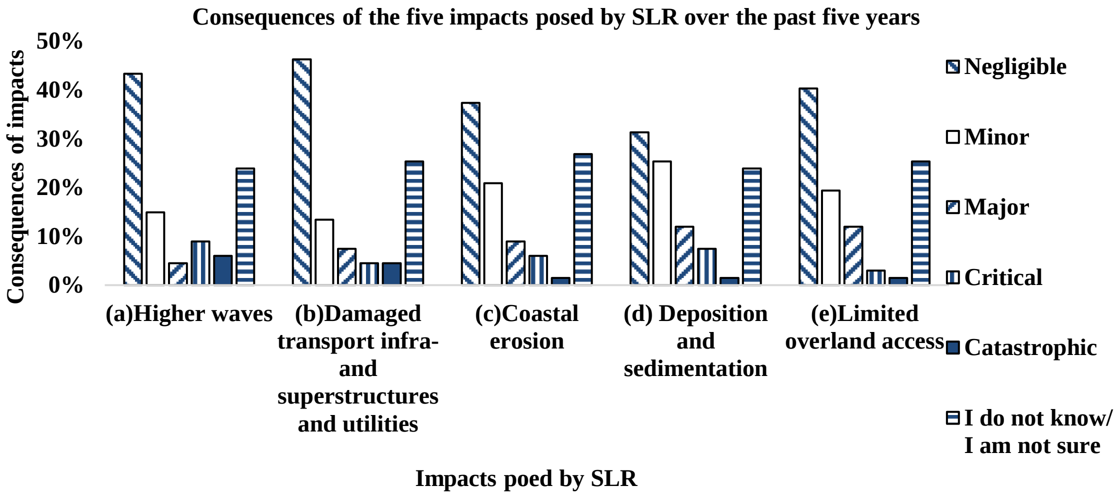

Fig. 3. Participants reporting different consequences of the five impacts posed by SLR over the past five years.

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

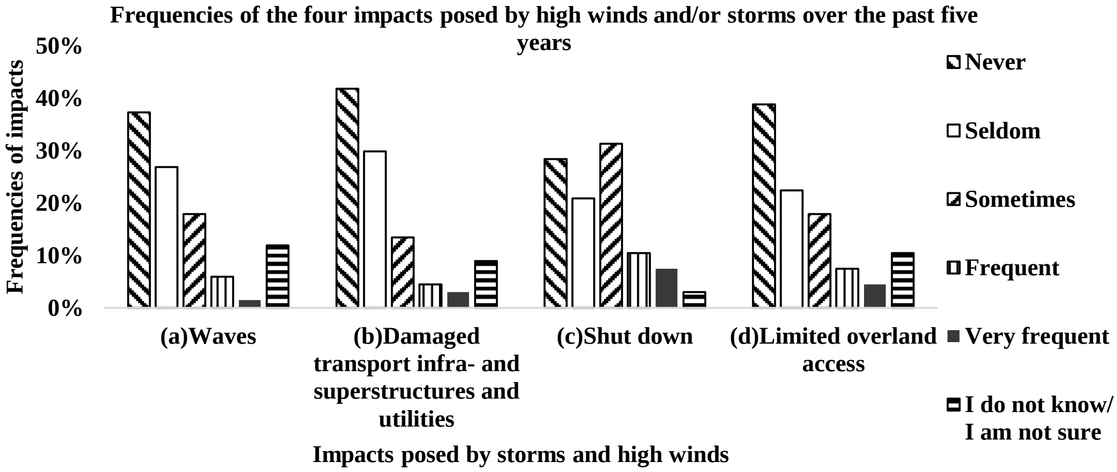

Fig. 4. Participants reporting different frequencies of the four impacts posed by high winds and/or storms over the past five years.

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

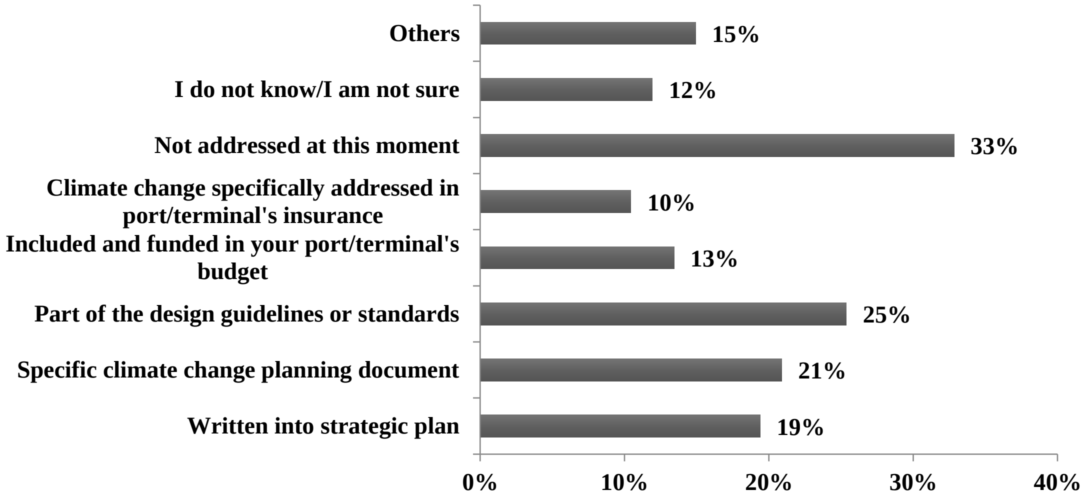

Fig. 5. Adaptation strategies and specific actions to build resilience at ports.

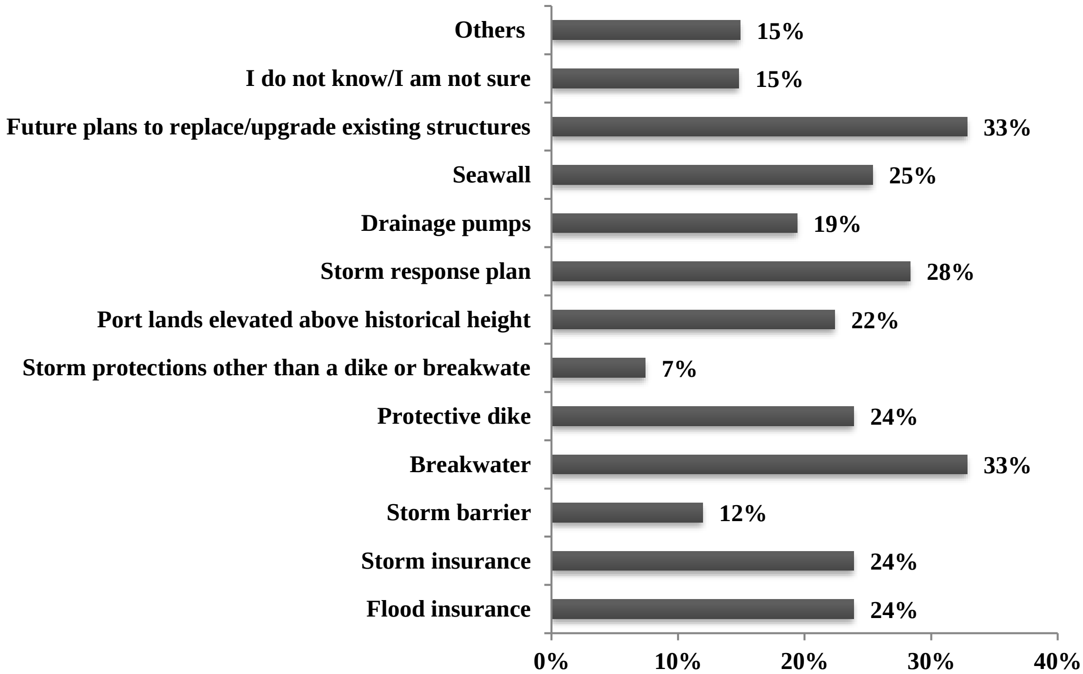

Fig. 6. Protective measures for adaptive responses to climate change at ports.

```
. signtest slr_a_soc_past= slr_a_soc_fth

Sign test

        sign |    observed    expected
-------------+------------------------
    positive |           5          17
    negative |          29          17
        zero |          18          18
-------------+------------------------
         all |          52          52

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

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

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

Fig. 7. An example of Stata output of the hypothesis testing between the past and the future scenarios.

```
. signtest slr_a_time_without= slr_a_time_with

Sign test

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

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

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

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

Fig. 8. An example of Stata output of the hypothesis testing between the two future scenarios.

Friedman Test

Ranks

	Mean Rank
slr_a_soc_past	1.52
slr_a_soc_without	2.15
slr_a_soc_with	2.33

Test Statistics[a]

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

a. Friedman Test

Fig. 9. An output example of the Friedman test.

Wilcoxon Signed Ranks Test

Ranks

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

a. slr_a_soc_without < slr_a_soc_past

b. slr_a_soc_without > slr_a_soc_past

c. slr_a_soc_without = slr_a_soc_past

Test Statistics[a]

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

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Fig. 10. An output example of the Post Hoc test.

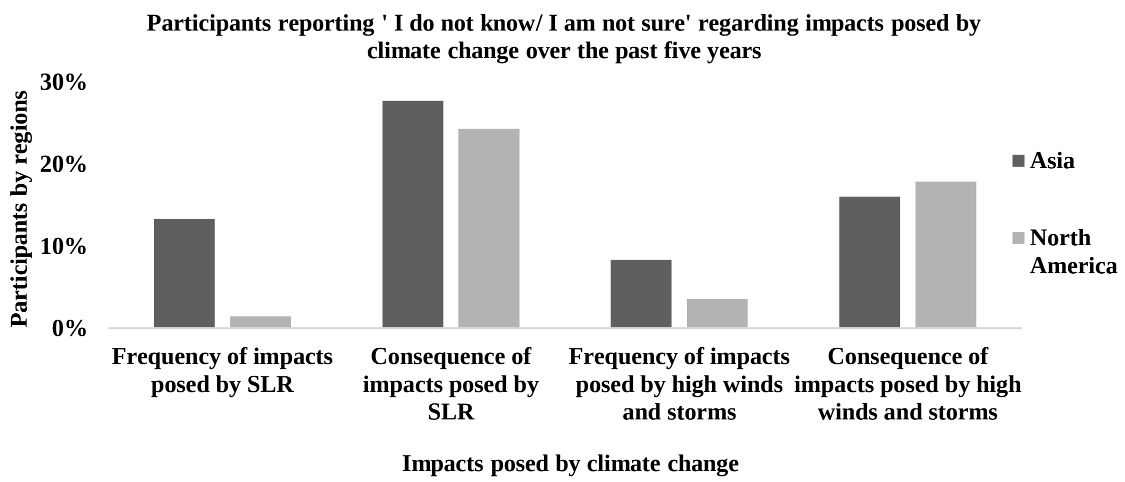

Fig. 11. Average percentage of participants divided by regions reporting ' I do not know/ I am not sure' regarding impacts posed by climate change over the past five years.

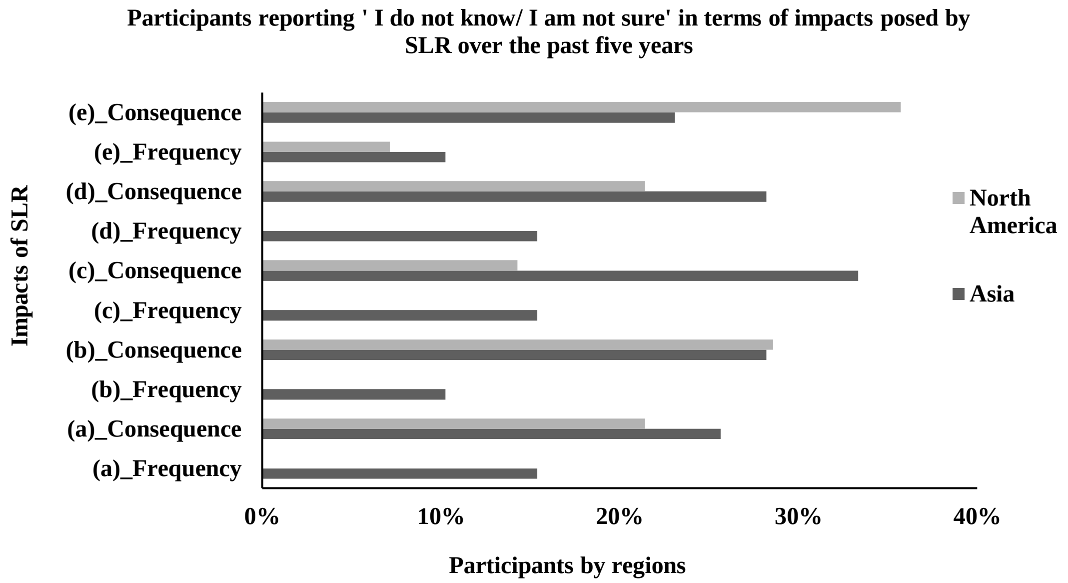

Fig. 12. Participants divided by regions reporting ' I do not know/ I am not sure' in terms of impacts posed by SLR over the past five years.

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

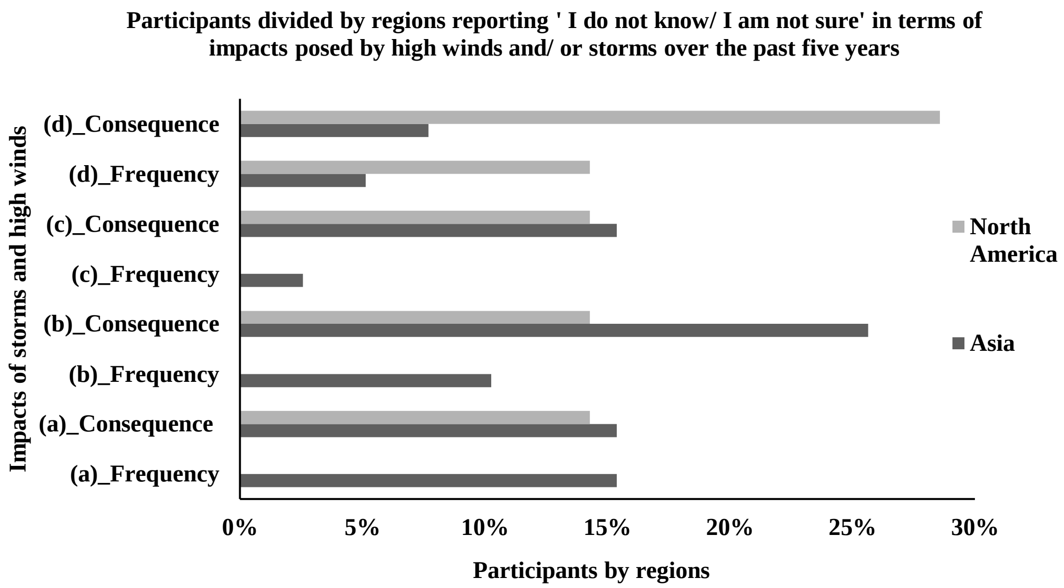

Fig. 13. Participants divided by regions reporting ' I do not know/ I am not sure' in terms of impacts posed by high winds and/ or storms over the past five years.

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