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**Port Decision Maker Perceptions on the Effectiveness of Climate Adaptation Actions**

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### Article

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

3  
4       Adolf K.Y. Ng<sup>1,2\*</sup>, Huiying Zhang<sup>1</sup>, Mawuli Afenyo<sup>1</sup>, Austin Becker<sup>1,3</sup>, Stephen Cahoon<sup>1,4</sup>,  
5       Shu-ling Chen<sup>1,5</sup>, Miguel Esteben<sup>6</sup>, Claudio Ferrari<sup>7</sup>, Yui-yip Lau<sup>1,8</sup>, Paul T.W. Lee<sup>9</sup>, Jason  
6       Monios<sup>1,10</sup>, Alessio Tei<sup>11</sup>, Zaili Yang<sup>1,12</sup>, Michele Acciaro<sup>13</sup>  
7

8       1 Transport Institute, University of Manitoba, Winnipeg, MB, Canada.

9       2 Department of Supply Chain Management, Asper School of Business, University of  
10      Manitoba, Winnipeg, MB, Canada.

11      3 Department of Marine Affairs, University of Rhode Island, Providence, RI, USA

12      4 Sense-T, University of Tasmania, Hobart, Australia

13      5 National Centre for Ports and Shipping, Australian Maritime College, University of  
14      Tasmania, Launceston, Australia

15      6 Graduate School of Frontier Sciences, University of Tokyo, Tokyo, Japan

16      7 Department of Economics, University of Genoa, Genoa, Italy

17      8 Division of Business, Hong Kong Community College, The Hong Kong Polytechnic  
18      University, Hong Kong, China

19      9 Institute of Maritime Logistics, Ocean College, Zhejiang University, Zhoushan, China

20      10 Kedge Business School, Marseille, France

21      11 School of Marine Science and Technology, Newcastle University, Newcastle, UK

22      12 Liverpool Logistics, Offshore and Marine Research Institute, Liverpool John Moores  
23      University, Liverpool, UK

24      13 Kühne Logistics University, Hamburg, Germany

25  
26      \* Corresponding author: Adolf, K.Y. Ng Email: [adolf.ng@umanitoba.ca](mailto:adolf.ng@umanitoba.ca) Telephone: +1 (204) 474-6594 Address: Transport Institute,  
27      University of Manitoba, Drake Centre, 181 Freedman Crescent, Winnipeg, MB, R3T 5V4, Canada.

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33

34 **PORT DECISION-MAKER PERCEPTIONS ON THE EFFECTIVENESS OF**  
35 **CLIMATE ADAPTATION ACTIONS**  
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37

38 **Abstract**

39 Effective adaptation to climate change impacts is fast becoming an important research topic  
40 nowadays. Hitherto, the perceptions and attitudes of stakeholders on climate adaptation actions  
41 are understudied, partly due to the emphasis on physical and engineering aspects during the  
42 adaptation planning process. Understanding such, the paper explores the perceptions of port  
43 decision-makers on the effectiveness of climate adaptation actions. The findings suggest that  
44 while port decision-makers are aware of potential climate change impacts and feel that more  
45 adaptation actions should be undertaken, they are sceptical about their effectiveness and value.  
46 This is complemented by a regional analysis on the results, suggesting that more tailor-made  
47 adaptation measures suited to local circumstances should be developed. The study illustrates  
48 the complexity of climate adaptation planning and of involving port decision-makers under the  
49 current planning paradigm.  
50

51 **Keywords:** Climate change, adaption, port, perception, survey  
52

53 **1. Introduction**  
54

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

79 Maritime transport moves more than 80% of global cargoes and significantly influences  
80 the world's economy (Ng and Liu 2014). Ports play pivotal roles in supply chains, as they  
81 connect ocean logistics with inland transport, which in turn drives the growth of regional and  
82 national economies. Given that ports are the interface where goods are traded across boundaries,  
83 climate change may cause significant economic losses to ports, influencing the regional

84 economy, the operation of supply chains and the lives of people in coastal cities. In particular,  
85 ports and the surrounding regions could pay a high price for climate change impacts, from the  
86 breakdown of day-to-day operations to infrastructure damage (and repairs) (Becker et al. 2016).  
87 Facing such risk, ports must take effective actions to ensure smooth operations and provide a  
88 quality service (Ng et al., 2016).

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

104 Some port decision-makers hesitate to engage in adapting to this new threat and prefer to  
105 gain more information and knowledge instead of making proactive investments (Zhang et al.,  
106 2017). There are many reasons why a port may wish to defer investment, especially when it  
107 comes to the protection against low-probability, high-impact, events such as tropical storms.  
108 Also, SLR is difficult to plan for, as the effects are incremental and the rate of rise remains  
109 uncertain. The “wait and see” approach raises the question: To what extent is it necessary or  
110 important for ports to plan and invest to adapt to climate change in the near future?  
111 Understanding such, this paper 1) provides an overview of perceptions and attitudes that port  
112 decision-makers currently hold towards climate adaptation actions; 2) offers strategic  
113 directions for future planning efforts; and 3) calls for more attention from scholars and  
114 practitioners to ports’ climate adaptation. Though also important, the issue of management and  
115 governance is not addressed, as it is beyond the scope of this study<sup>1</sup>.

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

120

## 121 **2. Theoretical Background, Research Framework and Methodology**

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

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<sup>1</sup> See Ng et al. (forthcoming(a)) and Zhang et al. (2017) for detailed discussions on climate adaptation management and governance.

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

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

144 H<sub>1</sub>: If there are no adaptation measures undertaken in the near future, port decision-makers  
145 perceive that SLR and strong storms due to climate change will have a more serious impact  
146 on ports.

147 H<sub>2</sub>: Port decision-makers perceive that adaptation measures based on IBPs would be  
148 effective in enhancing the resilience of port facilities and infrastructure to SLR and strong  
149 storms.

150  
151 Figure 1 provides an overview of the research framework. The online survey distributed  
152 was divided into three sections. In the first section, existing risks and impacts due to climate  
153 change are identified. In the second section, adaptation measures that have been taken in ports  
154 are discussed. Finally, two different scenarios (one with and one without adaption measures in  
155 the future) are presented.

156 [INSERT FIGURE 1 ABOUT HERE]

157  
158 To facilitate the study process, an exploratory survey was designed. As adaptation is still a  
159 relatively new research topic, limited data is available. Therefore, an online survey enabled a  
160 broad range of issues to be explored with relatively easy responses from managers operating  
161 different ports around the world.

162  
163 *2.1 Targeted ports, sampling, and respondents*

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

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

177 To enhance valid responses, the Dillman total design survey method was employed  
178 (Hoddinott and Bass 1986). For those that did not respond, a second mail of survey links and  
179 a cover letter were sent approximately one month after the initial mailing. By doing so, the  
180 number of incomplete questionnaires was kept to a minimum. By mid-2016, we received 82  
181 replies. After a screening process, 67 responses were deemed satisfactory to proceed with the  
182 analysis. The distribution of responses of ports from different continents can be found in Table  
183 1. Nearly 80% of the valid responses come from Asian and North American ports, thus creating  
184 an ideal platform for a comparative analysis between the two regions (to be illustrated in section  
185 3.3).

186  
187 [INSERT TABLE 1 ABOUT HERE]  
188

## 189 2.2 Questionnaire design and data processing

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

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

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

- 209 (1) timeframe (when you expect to see the impact of climate change for the first time);
- 210 (2) severity of consequences;
- 211 (3) likelihood (that the event will occur) (Yang et al., forthcoming).

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

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

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### 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

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

281  
282 [INSERT FIGURE 6 ABOUT HERE]  
283

284 In terms of specific protective measures that could be implemented to reduce climate risks  
285 (Figure 7), ports/terminal authorities were aware of protection measures available at the ports,  
286 such as breakwaters (33%), storm response plan (28%), storm insurance (24%), and protective  
287 dikes (24%). 33% of the respondents planned to replace/upgrade existing structures. This  
288 suggested that ports decision-makers had been implementing strategies and actions based on  
289 issues and concerns specific to their needs but not addressing the problem holistically. However,  
290 15% indicated that they were not aware of any protective measures implemented at their ports.

291  
292 [INSERT FIGURE 7 ABOUT HERE]  
293

### 294 3.2 Hypothesis testing

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

307  
308 The same method was adopted to test  $H_2$ . An example can be found in Figure 9. The sign  
309 test was conducted 21 times regarding SLR, as seven adaptation measures were designed to  
310 address five impacts and each adaptation measure had three parameters (timeframe, severity of  
311 consequence, and likelihood). Each sign test outputs three  $p$ -values, two for the one-sided tests  
312 and the third one for the two-sided test. However, only six out of the 63 statistical indicators  
313 are less than 0.05. Except for one  $p$ -value from a two-sided test which indicated a neutral result,  
314 the other five significant results are from “slr\_c\_prob”, “slr\_d\_time”, “slr\_d\_soc”,  
315 “slr\_d\_prob”, and “slr\_e2\_prob”. Interestingly, all the five one-sided tests provided “negative”  
316 results. The inference from the  $p$ -value of “slr\_d\_time” suggested that deposition and  
317 sedimentation caused by SLR would occur sooner if no adaptation measures are implemented  
318 in the future. On the contrary, the remaining four statistically significant results indicate that  
319 impacts can be even worse with adaptation measures in the future.

320  
321 Turning to the high winds and storms, five adaptation measures were designed to address  
322 the four impacts. 15 comparisons were tested regarding the three parameters (timeframe,



323 severity of consequence, and likelihood). Each comparison had three *p*-values and among all  
324 the 45 indicators, 10 *p*-values were statistically significant.

325

326 [INSERT TABLE 4 ABOUT HERE]

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

333

### 334 3.2.2 Verification of hypothesis testing

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

343

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

351

352

## 353 3.3 Regional analysis

### 354 3.3.1 Knowledge about climate change impacts

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

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

365

366 [INSERT FIGURE 12 ABOUT HERE]

367

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

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

379  
380 [INSERT FIGURE 13 ABOUT HERE]

381  
382 Figure 14 revealed that respondents had better knowledge regarding the frequency of the  
383 impacts posed by high winds and/or storms than their consequences. North American  
384 respondents had better knowledge of these potential climate change impacts. They were more  
385 familiar with the impacts of “higher waves”, “damaged transport infra- and superstructures and  
386 utilities” and “downtime”, whereas Asian respondents were more knowledgeable on the  
387 impacts of “limited overland access”. In this case, the major difference between these two sets  
388 of respondents fell into “damaged transport infra- and superstructure and utilities”. They  
389 reported similar perceptions about the impact of “downtime”. However, a significant gap of  
390 perceived risk with regards to limited overland access” impact was detected for North  
391 American respondents.

392  
393 [INSERT FIGURE 14 ABOUT HERE]

394  
395 *3.3.2 Effectiveness of adaptation measures*

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

407  
408 The results among North American ports did not show any significant differences between  
409 the future scenarios with and without SLR adaptation measures. Similarly, only two *p*-values  
410 (of the 45 indicators) were below the significance level, suggesting that respondents perceived  
411 that adaptation measures would be beneficial to mediate the impacts posed by high winds  
412 and/or storms. They believed that new or extended breakwaters would effectively decrease the  
413 probability of damage associated with higher waves. The measure “improvement in  
414 management to prevent effects” was expected to postpone the timeframe of the first observation  
415 of port downtime due to higher winds and/or storms.

416  
417 **4. Discussion**

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

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<sup>2</sup> This may due to the fact that the erosion problem is less prominent in Asia. This is subject to further research.

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

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

434

#### 435 *4.1. Doing something (anything) is better than doing nothing*

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

444

#### 445 *4.2 Those with more knowledge have more faith in adaptation solutions*

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

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

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<sup>3</sup> It should be noted that, the statement is the view point of the authors on the potential rationale for decision-makers.

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

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

477

#### 478 *4.3 IBPs May Not Be Appropriate*

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

492

#### 493 *4.4 Lack of incentives for adaptation*

494 Another finding from our study concerns port decision-makers' attitudes towards  
495 adaptation measures. Even with the availability of adaptation plans and programs, they often  
496 prefer not to implement them, as they are too costly in terms of money, time, or human  
497 resources. A good example was the port of San Diego (PSD), where its port authority  
498 suspended the adaptation component of its *Climate Mitigation and Adaptation Plan* (CMAP)  
499 a year after it was publicized in 2013. The reason for the suspension is still not totally clear but  
500 according to Messner et al. (2016), the lack of focus and understanding and the low level of  
501 urgency amongst stakeholders are key factors. This is further made worse by the uncertainties  
502 surrounding the implementation of the plan. The current planning paradigm in adaptation is  
503 often initiated, and drafted, by the port authority based on experiences from climate change  
504 mitigation, especially the "top-down" approach in controlling/achieving CO<sub>2</sub> emission  
505 targets/milestones. This often results in the (excessive) "merging" of climate adaptation and  
506 mitigation strategies and measures (e.g., PSD's CMAP). Understanding such, a paradigm shift  
507 from "go it alone" (largely based on the port authority) to a more "collaborative" approach is  
508 necessary. Such a view is also echoed by Becker et al. (2018). Though CMAP is yet to be  
509 implemented, it is a blueprint for the best way forward to addressing the problem of ports'  
510 adaptation to climate change.

511

512 **5. Conclusion**

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

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

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

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

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659 **Table 1**

660 Geographical distribution of valid responses.

<b>REGION</b>	<b>COUNTRY/REGION</b>	<b>VALID RESPONSE(S)</b>	<b>PERCENTAGE</b>
	Taiwan	15	22%
Asia	China (incl. Hong Kong)	17	25%
	Japan, South Korea, UAE and the Philippines	7	10%
	North America	USA	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 <sup>4</sup>		4	6%
<b>TOTAL</b>		<b>67</b>	<b>100%</b>

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662

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<sup>4</sup> Due to the sensitive nature of the issue, some ports are unwilling to release their identity, even on which continent their ports are located.



663 **Table 2**

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

ADAPTATION	PARAMETER	POSITIVE_O NE SIDED	NEGATIVE_ON E SIDED	DIFFERENT_TW O SIDED
slr_a	slr_a_time	0.7878	0.345	0.69
	slr_a_soc	0.9552	0.0877	0.1755
	slr_a_prob	0.7566	0.3642	0.7283
slr_b1	slr_b1_time	0.779	0.3506	0.7011
	slr_b1_soc	0.779	0.3506	0.7011
	slr_b1_prob	0.655	0.5	1
slr_b2	slr_b2_time	0.9449	0.1077	0.2153
	slr_b2_soc	0.7709	0.3555	0.7111
	slr_b2_prob	0.5	0.655	1
slr_c	slr_c_time	0.8761	0.221	0.4421
	slr_c_soc	0.9599	0.0814	0.1628
	slr_c_prob	0.9947	<b>0.0173</b>	<b>0.0347</b>
slr_d	slr_d_time	0.9853	<b>0.0354</b>	0.0708
	slr_d_soc	0.9904	<b>0.0261</b>	0.0522
	slr_d_prob	0.9825	<b>0.0401</b>	0.0801
slr_e1	slr_e1_time	0.8275	0.2858	0.5716
	slr_e1_soc	0.8852	0.2122	0.4244
	slr_e1_prob	0.5806	0.5806	1
slr_e2	slr_e2_time	0.8595	0.2366	0.4731
	slr_e2_soc	0.9786	<b>0.0494</b>	0.0987
	slr_e2_prob	0.655	0.5	1

665

666 *Note:* 1) A/b/c/d/e from slr\_a/b/c/d/e is the impact caused SLR. 2) A/b<sub>1</sub>/b<sub>2</sub>/c/d/e<sub>1</sub>/e<sub>2</sub> from slr\_  
667 a/b<sub>1</sub>/b<sub>2</sub>/c/d/e<sub>1</sub>/e<sub>2</sub>\_time/soc/prob is the specific adaptation measure. A is to build new breakwaters and/or increase  
668 their dimensions; b<sub>1</sub> is to improve transport infra- and superstructures resilience to flooding; b<sub>2</sub> is to elevate port  
669 land; c is to protect coastline and increase beach nourishment programs; d is to increase and/or expand dredging;  
670 e<sub>1</sub> is to improve quality of land connections to port/terminal; e<sub>2</sub> is to diversify land connections to port/terminal.  
671 3) Prob, time, soc are likelihood, timeframe, and severity of consequence, respectively.

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673

674 **Table 3**

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

ADAPTATION	PARAMETER	POSITIVE_O	NEGATIVE_O	DIFFERENT_TW
		NE SIDED	NE SIDED	O SIDED
	hw_a_time	0.9962	<b>0.01</b>	<b>0.0201</b>
hw_a	hw_a_soc	0.8192	0.2923	0.5847
	hw_a_prob	0.1808	0.8998	0.3616
	hw_b_time	0.9996	<b>0.0017</b>	<b>0.0033</b>
hw_b	hw_b_soc	0.9622	0.0843	0.1686
	hw_b_prob	0.5775	0.5775	1
	hw_c_time	0.9993	<b>0.0022</b>	<b>0.0043</b>
hw_c	hw_c_soc	0.9461	0.1148	0.2295
	hw_c_prob	0.1002	0.9506	0.2005
	hw_d1_time	0.9999	<b>0.0005</b>	<b>0.0009</b>
hw_d1	hw_d1_soc	0.9646	0.0748	0.1496
	hw_d1_prob	0.1725	0.9075	0.3449
	hw_d2_time	1	<b>0.0001</b>	<b>0.0003</b>
hw_d2	hw_d2_soc	0.8998	0.1808	0.3616
	hw_d2_prob	0.221	0.8761	0.4421

677

678 *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  
 679 storms. 3) A/b/c/d<sub>1</sub>/d<sub>2</sub> from hw\_a/b/c/d<sub>1</sub>/d<sub>2</sub>\_time/soc/prob is the specific adaptation measure. A is to build new  
 680 breakwaters and/or increase their dimensions; b is to improve transport infra- and superstructures resilience to  
 681 flooding; c is to improve management to prevent effects; d<sub>1</sub> is to improve quality of land connections to  
 682 port/terminal; d<sub>2</sub> is to diversify land connections to port/terminal. 4) Prob, time, soc present likelihood, timeframe,  
 683 and severity of consequence, respectively.

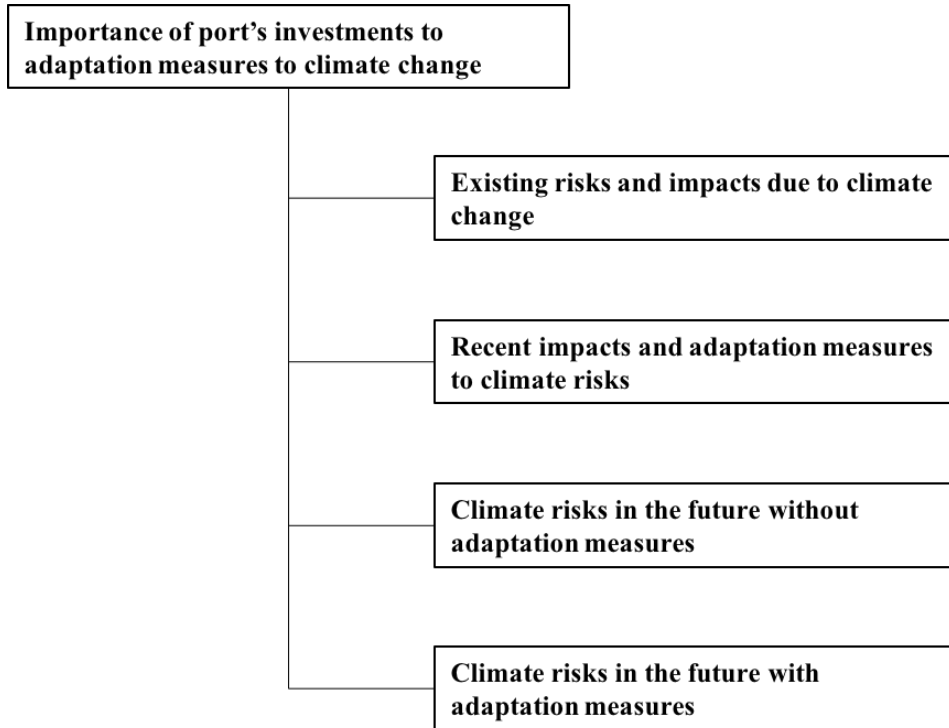
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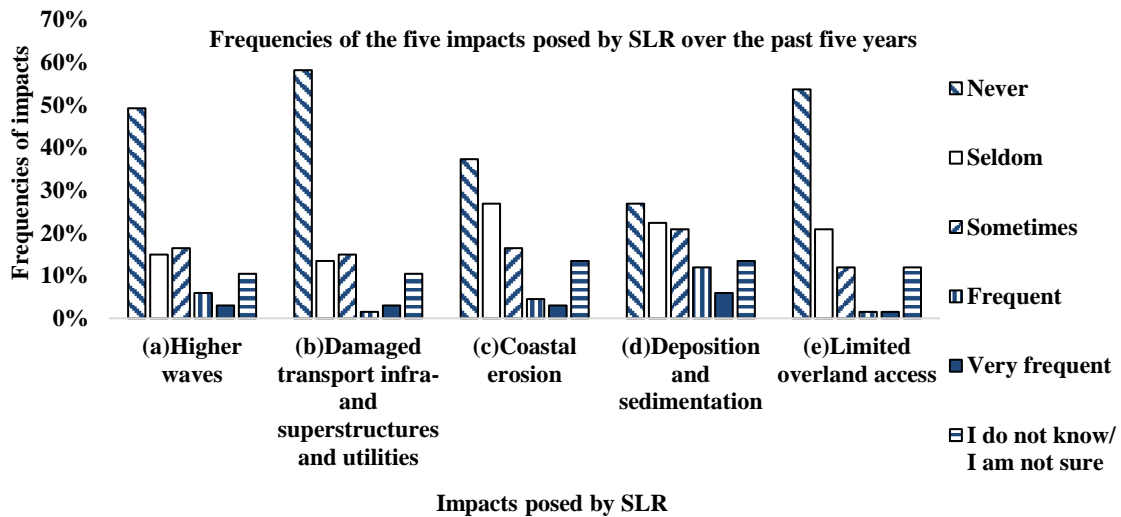
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**Fig. 1.** Research framework. *Source:* authors.



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

697 *Note:* (a) SLR resulted in higher waves that damaged your port/terminal's facilities and/or ships berthed alongside.

698 (b) Transport infra- and superstructures (like cranes and warehouses) and utilities in your port/terminal were

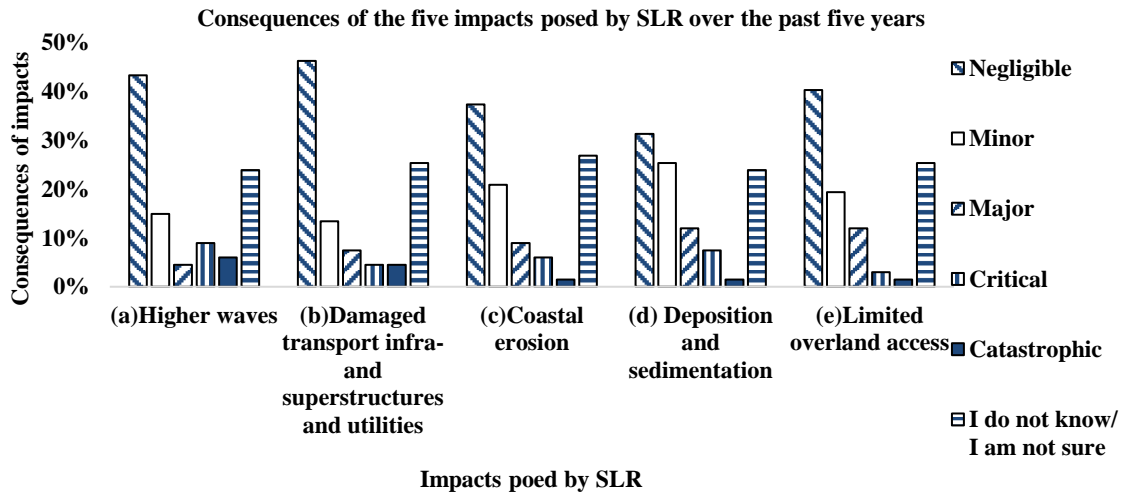
699 flooded or damaged because of SLR. (c) Coastal erosion occurred at or adjacent to your port/terminal. (d)

700 Deposition and sedimentation occurred along your port/terminal's channels. (e) Overland access (road, railway)

701 to your port/terminal was limited due to more incidents of flooding.

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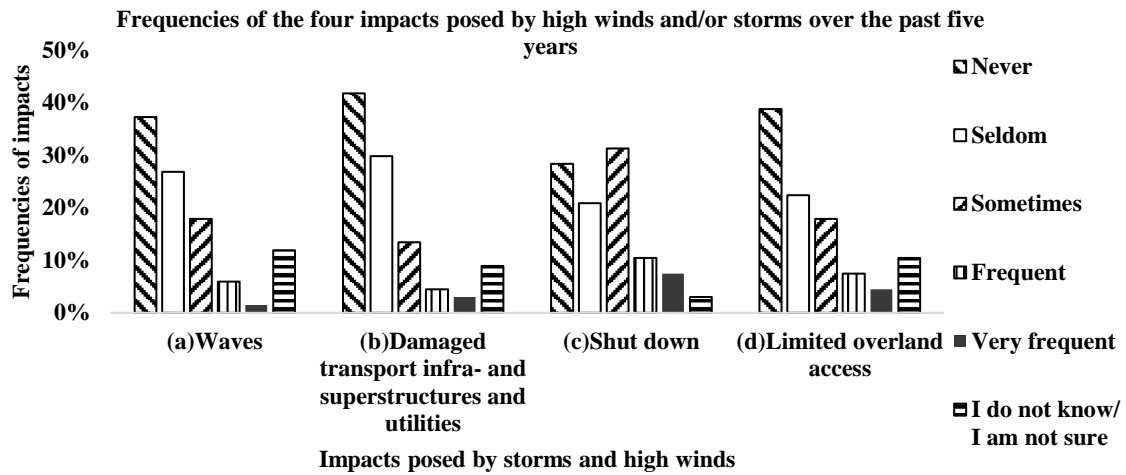
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**Fig. 3. Participants reporting different consequences of the five impacts posed by SLR over the past five years.**

*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.



715

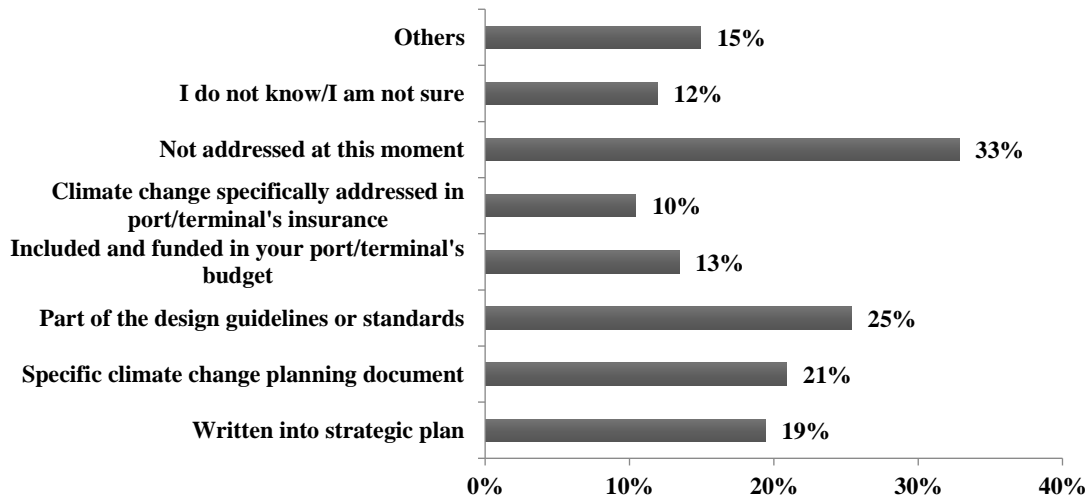
716

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

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

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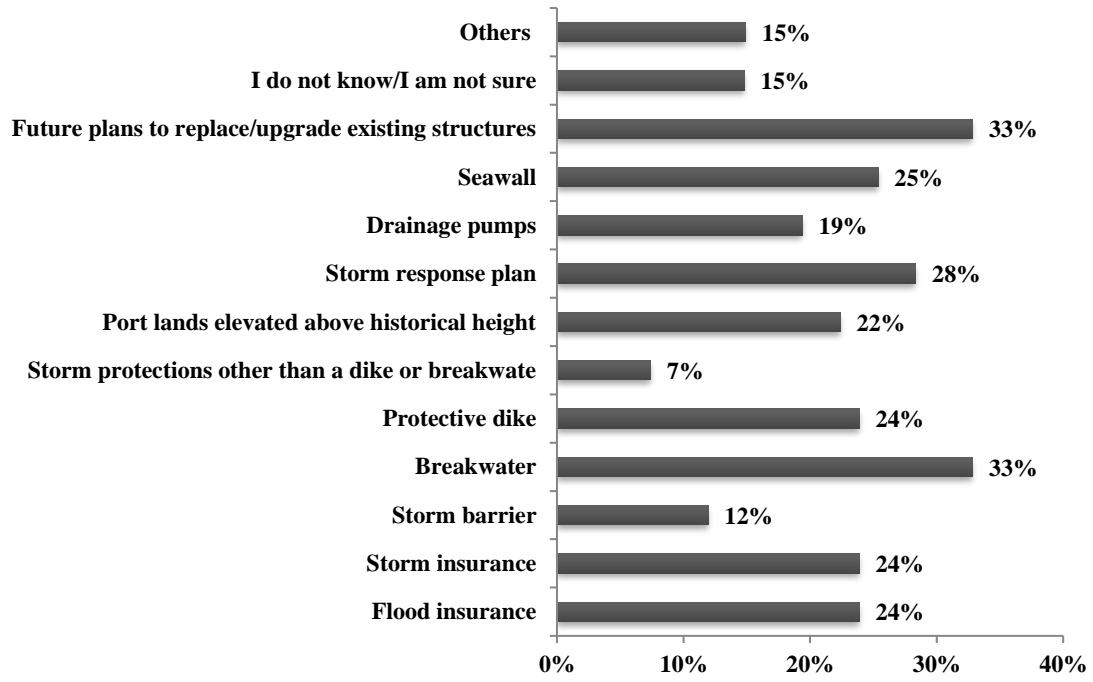
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727

728

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

729



730

731

732

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

733



```
. 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

734

735

736

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

737

738

```
. 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\_time\_without - slr\_a\_time\_with = 0 vs.

Ha: median of slr\_a\_time\_without - slr\_a\_time\_with > 0

Pr(#positive >= 11) =

Binomial(n = 25, x >= 11, p = 0.5) = 0.7878

Ho: median of slr\_a\_time\_without - slr\_a\_time\_with = 0 vs.

Ha: median of slr\_a\_time\_without - 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\_time\_without - slr\_a\_time\_with = 0 vs.

Ha: median of slr\_a\_time\_without - slr\_a\_time\_with != 0

Pr(#positive >= 14 or #negative >= 14) =

min(1, 2\*Binomial(n = 25, x >= 14, p = 0.5)) = 0.6900

739

740

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

742

➔ **Friedman Test**

	Mean Rank
slr_a_soc_past	1.52
slr_a_soc_without	2.15
slr_a_soc_with	2.33

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

a. Friedman Test

743

744

745

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

746

## Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
slr_a_soc_without - slr_a_soc_past	Negative Ranks	5 <sup>a</sup>	13.00	65.00
	Positive Ranks	29 <sup>b</sup>	18.28	530.00
	Ties	18 <sup>c</sup>		
	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<sup>a</sup>

	slr_a_soc_wit hout - slr_a_soc_pa st
Z	-4.189 <sup>b</sup>
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

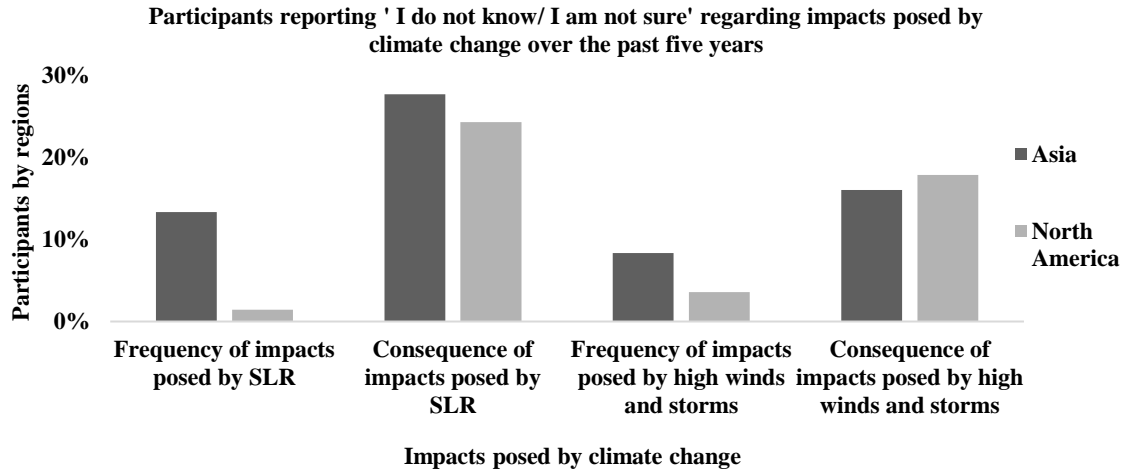
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**Fig. 10.** An output example of the Post Hoc test.

750



751

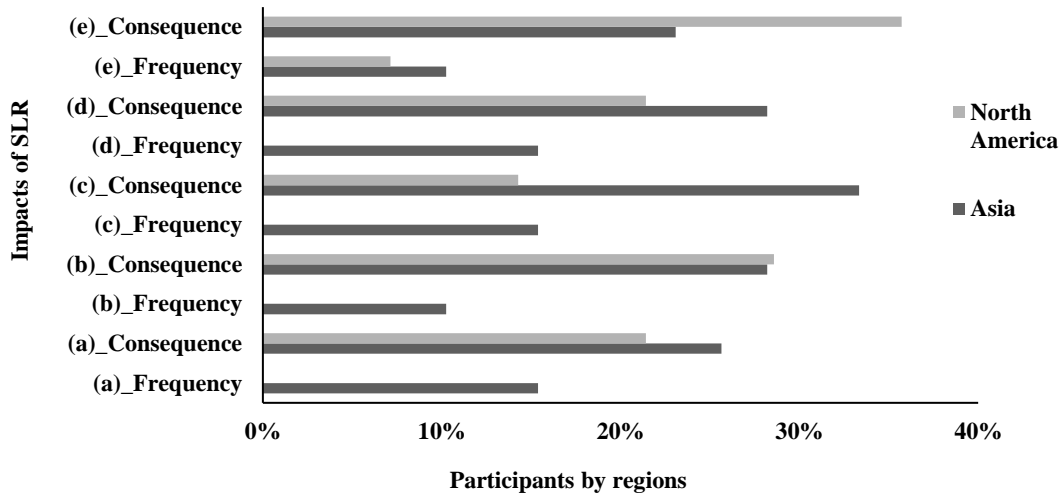
752

753 **Fig. 11.** Average percentage of participants divided by regions reporting ' I do not know/ I am

754 not sure' regarding impacts posed by climate change over the past five years.

755

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



756

757

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

760 *Note:* (a) SLR resulted in higher waves that damaged your port/terminal's facilities and/or ships berthed alongside.

761 (b) Transport infra- and superstructures (like cranes and warehouses) and utilities in your

762 port/terminal were flooded or damaged because of SLR. (c) Coastal erosion occurred at or adjacent to your

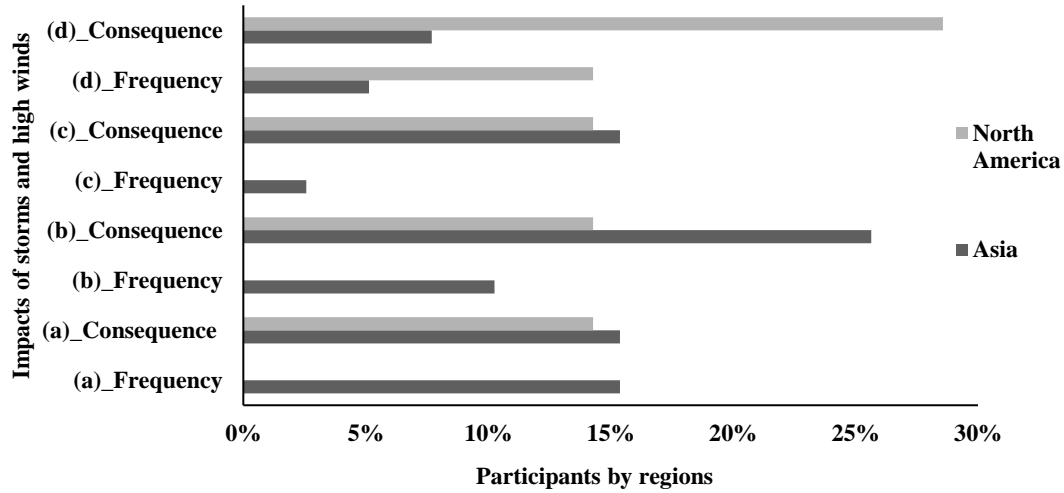
763 port/terminal. (d) Deposition and sedimentation occurred along your port/terminal's channels. (e) Overland access

764 (road, railway) to your port/terminal was limited due to more incidents of flooding.

765

766

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



767

768

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

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

776

777