

PORT ADAPTATION TO SEA LEVEL RISE: LESSONS FROM PRESENT EXAMPLES OF LAND SUBSIDENCE

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INTRODUCTION

According to the Intergovernmental Panel on Climate Change 5th Assessment Report, or IPCC 5AR (2013), sea level rise (SLR) could be in the order of 26 to 98 cm by 2100. However, more onerous predictions, such as those set forth in recent probabilistic process-based models by Kopp et al. (2017), or Bars et al., (2017), indicate that SLR could be almost in the order of almost 3m by the end of the 21st century.

As a result of sea level rise a number of authors have stated that many ports and coastal communities would be forced to relocate or attempt expensive adaptation countermeasures (Yamamoto and Esteban, 2016). However, most of the forecasted problems and their knock-on consequences on coastal communities remain hypothetical, despite a number of past examples of relative sea level rise due to earthquake induced subsidence or groundwater extraction (Jamero et al, 2016, 2017, Takagi et al., 2016, Esteban et al., 2017).

In order to better understand the consequences of future sea level rise the authors have analysed the effects of two instances land subsidence that have taken place in the 20th and early 21st century, and the adaptation measures that ports and other low-lying areas have adopted in the northern Japanese region of Tohoku following the 2011 Earthquake Tsunami, and Jakarta in Indonesia (where groundwater extraction has been inducing rates of subsidence of 10-20cm per year in several parts of the city, Takagi et al, 2017). To date, the authors are not aware of any other work that has systematically attempted to learn from real examples of land subsidence as a proxy to study the effects of SLR on ports, despite a number of calls for more research to be done on the subject (Becker et al., 2013).

METHODOLOGY

The authors conducted a large number of field surveys through the areas to document the measures that different areas around the world area adopting to adapt to relative sea level rise (see Takagi et al., 2016, Esteban et al., 2015, etc).

The present work continues the line of work employed by the authors by conducting field surveys of ports and other docking areas that have been raised following land subsidence. Key informant interviews were conducted with port officials and other stakeholders, in order to determine the types of measures that were

attempted. These semi-structured interviews typically lasted for about an hour, and were held between authors and any number of port employees that were willing to participate in them. For the case of the Indonesia ports, two of the authors of the study served as interpreters to the other authors present. For the case of the Japanese ports the main author and other authors conducted communication directly in Japanese. Both Indonesian and Japanese engineers spoke some English, and some communication was also conducted in this language. The interview generally started by asking some general questions about the port (size, main activities, current estate of reconstruction), and then moved onto questions regarding the cost of adaptation measures against land subsidence.

RESULTS

The results indicate that the preferred adaptation mechanism appears to be the elevation of port areas by piling any available soil or rubble, and then re-surfacing to obtain a smooth surface (see Fig. 1 and 2). While these results would appear obvious, they provide real evidence and lessons for other ports that will inevitable have to attempt similar adaptation strategies in the future.



Figure 1 - Port adaptation to SLR in Jakarta: raising wharfs



Figure 2 - Elevating and resurfacing port areas in Japan

The authors also asked respondents to indicate the perceived limits to adaptation against a range of SLR scenarios (see Table 1). The most critical respondents were those in Japan, who highlighted how earthquake considerations would limit adaptation to up to +1.0m SLR, before additional (more expensive) countermeasures had to be employed.

Table 1. Perception of different limits to adaptation by port officials at Ishinomaki port. Green indicates no perceived limits, yellow indicates the beginning of problems, red the limits to adaptation.

Sea Level Rise	Technological Limits	Cost-Benefit Limits	Financial Barriers	Social Conflict Barriers
+ 0.5m				
+ 0.51 - 1.0m				
+ 1.01 - 2.0m	Earthquake considerations			
+ 2.01 - 4.0m	Earthquake considerations			
+ 4.01 - 8.0m	Earthquake considerations		Better to relocate?	

CONCLUSIONS

By studying how ports have adapted to land subsidence in Japan and Indonesia, it is possible to try to understand the effects that future SLR will have on such critical transport infrastructure.

While adaptation might result in additional costs that would not be incurred if more stringent mitigation strategies were employed, there seems to be no significant technological limits to adaptation in ports, at least for the SLR that is likely to take place in the 21st century.

Nevertheless, the port operators interviewed did highlight a number of important considerations, and how such issues are likely to impact on the finance and

operations of the various ports in the middle and long-term. It is important to take these into account to inform future adaptation strategies in other port, and in order to highlight the importance of more stringent mitigation targets, to avoid such additional costs to human societies.

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