DESIGNING PORT INFRASTRUCTURE FOR SEA LEVEL CHANGE: A SURVEY OF U.S. ENGINEERS

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Abstract

Seaports are particularly vulnerable to the impacts of climate change due to their coastal location (Fig. 1). With the potential threat of up to 2.5 m in sea level rise by 2100, resilient port infrastructure is vital for the continued operation of ports. Engineers play a pivotal role in improving the resilience of ports, as they are responsible for designing the infrastructure that needs to be adequately prepared for future sea level change (SLC). However, incorporating SLC into the design specifications of port infrastructure projects is a challenging task due to the uncertainty of SLC projections, the long service lives of port infrastructure, and the differing guidelines and recommendations for managing SLC. Through an online survey of 85 U.S. port and marine infrastructure engineers, this research explores the engineering community's attitude and approach to planning for SLC for large-scale maritime infrastructure projects (e.g., Fig.2). Survey findings highlight the extent that projects incorporate SLC, the wide range of factors that drive the inclusion of SLC, and the numerous barriers that prevent engineers from incorporating SLC into design. This research emphasizes that traditional engineering practices may no longer be appropriate for dealing with climate change design variables and their associated uncertainties. Furthermore, results call for collaboration among engineers, port authorities, and policy makers to develop design standards and practical design methods for designing resilient port infrastructure.

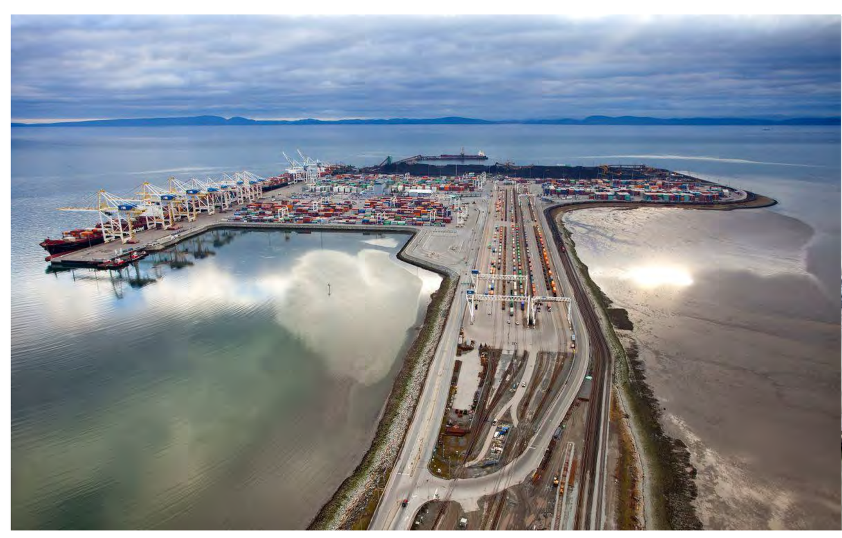


Figure 1. Port of Vancouver. Photo: The Globe and Mail, 2018

Figure 2. Seaport Construction. Photo: T. Slinn

Introduction

Climate change presents new design implications and variables that engineers did not have to consider in the past (Ahern, 2011). There are strong economic and social incentives for seaports to provide long-term resilience against climate conditions. For example, service disruptions can cost billions of dollars (Haveman & Shatz, 2006) and impact the livelihoods of those who depend on the port (Becker et al., 2013). Incorporating SLC into designs can be a challenging task, especially due to the fact that there is significant uncertainty with future SLC projections (Church et al., 2013; Pachauri et al., 2014; Kopp et al., 2014). Additionally, there are several agencies and organizations such as the U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), and local and state governments that provide their own guidance but use differing scales, projections, and uncertainties of SLC (Fig. 4; Table 1). Some port authorities, such as the Port Authority of New York and New Jersey (PANYNJ), have also adopted their own climate resilience guidelines (Fig. 3). Therefore, the engineering community needs to develop systematic and practical methods for assessing the impacts of SLC on port and marine infrastructure (Becker, Toilliez & Mitchell, 2015).

Table 1. State and Local SLC Guidance Comparison

Guidance Document	Source of SLC Data	SLC Projection
NYC Mayor's Office of Recovery & Resiliency: Climate Resiliency Design Guidelines (2017)	NYC Panel on Climate Change (NPPC)	2050: 11 to 21 in. 2080: 18 to 39 in.
State of California Sea-Level Rise Guidance (2018)	IPCC fifth assessment: RCP 8.5	Projects with lifespan up to 2050: 1.1 to 2.7 ft. Projects with lifespan beyond 2050: 2.4 to 3.4ft.

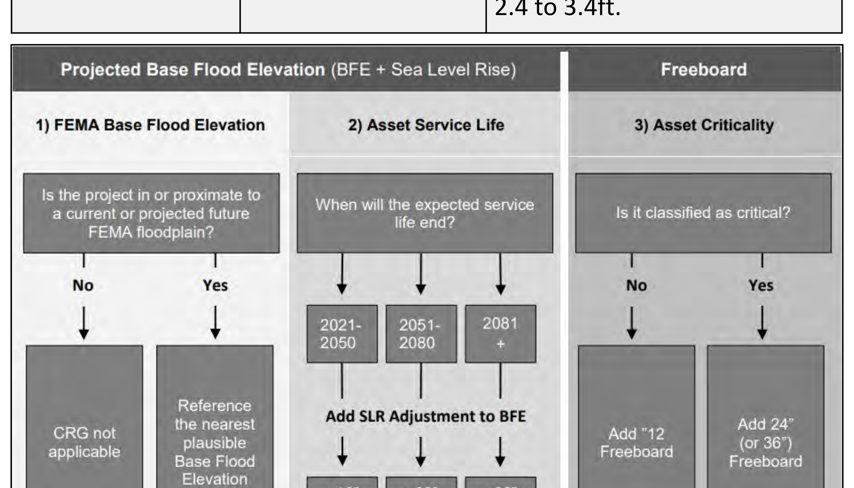


Figure 3. PANYNJ SLC Design Guidance (PANYNJ, 2018).

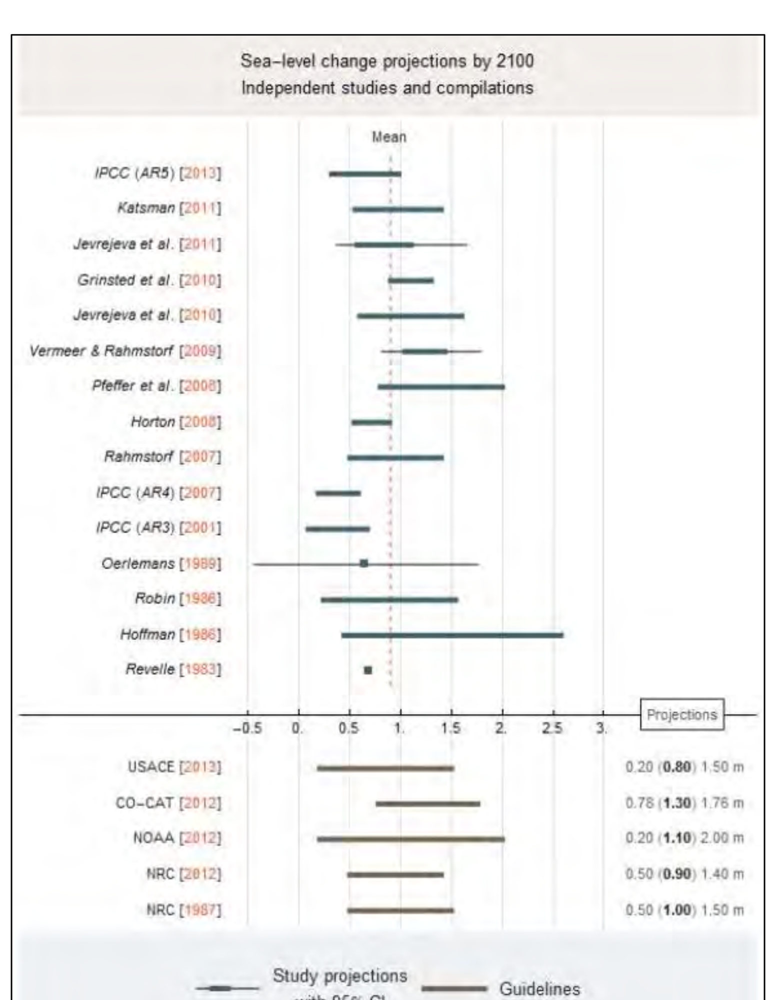


Figure 4. Compared SLC Studies (Becker, Toilliez & Mitchell, 2015).

Methods – Online Survey of U.S. Port Engineers

Overcoming the challenges engineers face with regards to designing port infrastructure for SLC, and advancing strategies to design more resilient infrastructure, requires a baseline assessment of the current state of the practice. Thus, this exploratory survey addressed the following questions:

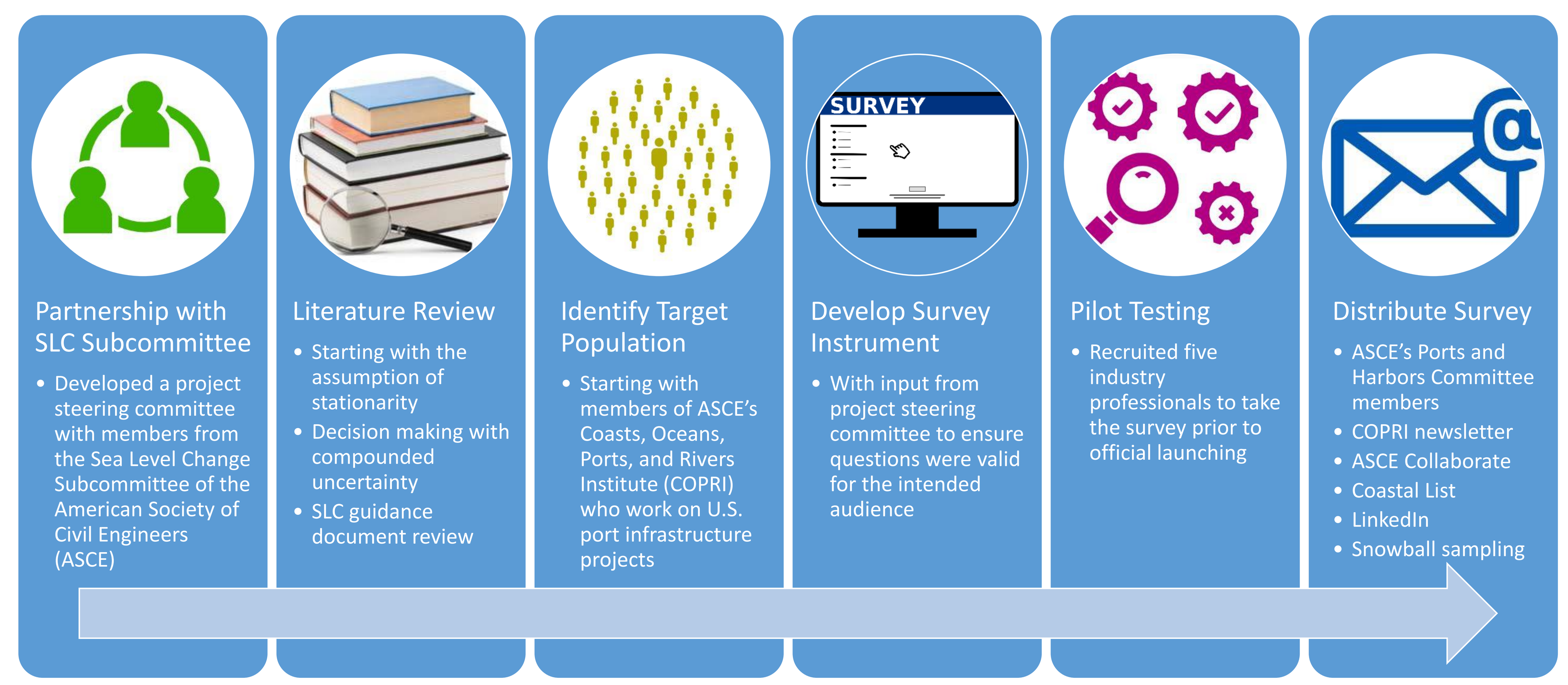
Research Questions

RQ 1. In what capacity are port infrastructure designers incorporating a SLC projection into their design specifications for large-scale port engineering projects?

RQ 2. Where do incentives and disincentives originate for US engineering firms to incorporate SLC into the design specifications of large-scale port engineering projects?

RQ 3. For engineering firms that are incorporating SLC, what strategies are the port infrastructure designers in those firms implementing to cope with the scientific uncertainty of sea level change?

Research Design



Overview of Responses

Total number of useable responses: **85**

- 31 different consulting firms represented
- 11 different port authorities represented
- 59% of respondents had over 15 years of experience
- 81% self-identified as a project manager or someone who makes final design decisions

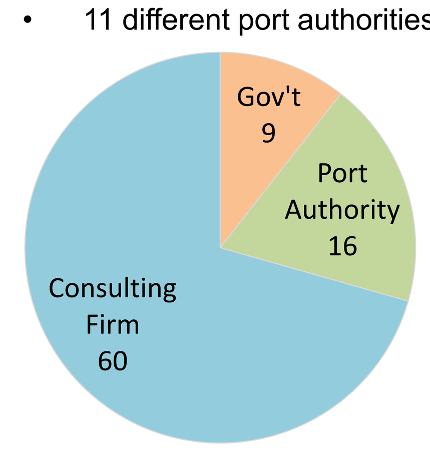


Figure 5. Respondents by organization type

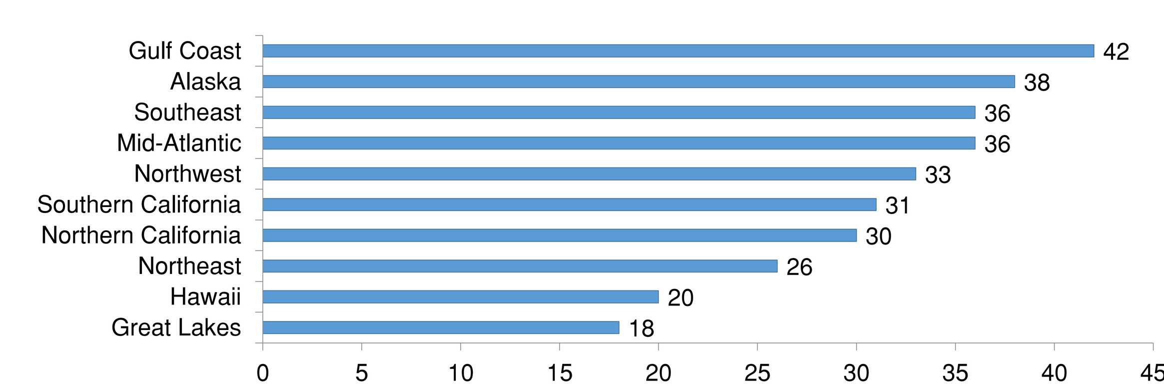


Figure 6. Number of respondents with experience in US coastal regions

Results – RQ 1

Key Findings

- In aggregate, respondents indicated that **43% (SD: 39%)** of the projects they worked on in the past five years have incorporated SLC
- The average percent of projects that incorporated SLC is significantly higher for respondents that work for an organization with a policy/planning document that communicates how future SLC should be incorporated into design

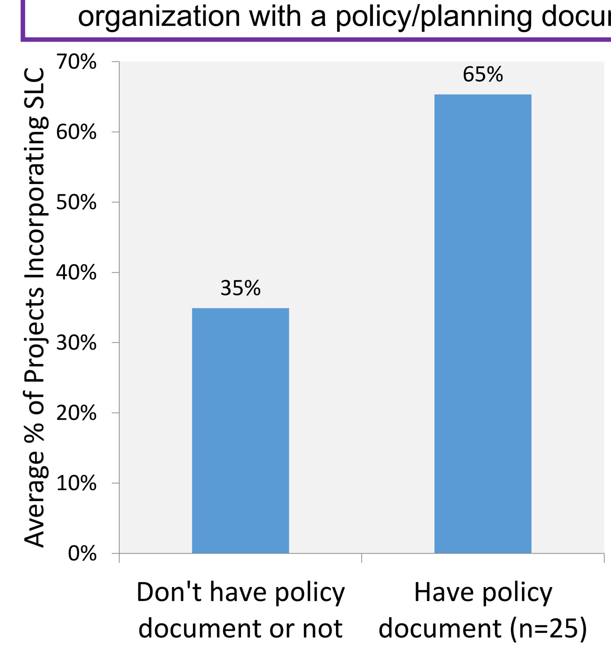


Figure 7. The effect of a policy document on the frequency of incorporating SLC into design

Respondents were asked how many port infrastructure projects they have played a role in designing over the past five years, and as a follow up question, how many of those projects incorporated SLC. Respondents were also asked if the organization they work for has a policy/planning document that communicates how future SLC should be incorporated into port infrastructure projects. Results show a correlation where respondents from an organization with a policy/planning document responded that they have worked on an average of 30% more projects that incorporate SLC in the past five years (Fig. 7). A possible explanation for this correlation is that a formal document provides solid ground to stand on, whereas engineers without documented support may be less willing to take the personal and professional risk to make design recommendations.

Results – RQ 2

Key Findings

- Incorporating SLC is motivated by a variety of factors, and can originate from engineers, port authorities, or regulators
- Lack of design standards were a key barrier to incorporating SLC

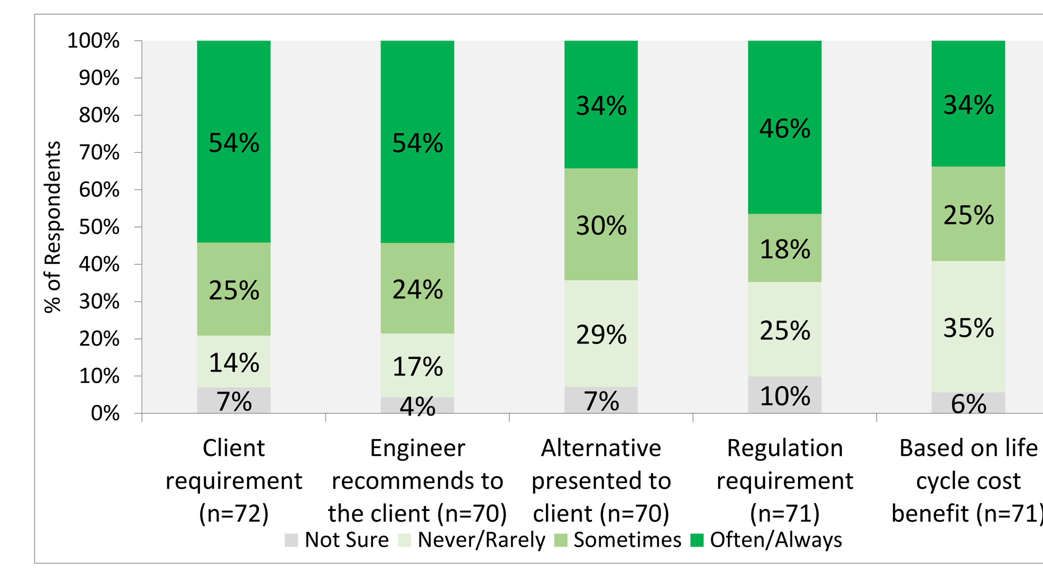


Figure 8. Potential factors that may cause engineers to incorporate SLC into design

Respondents were asked what factors cause their organization to add a SLC design component to a project. Since the *Often/Always* response received the highest percentage of respondents for nearly every factor, these results suggest that the incentive to incorporate SLC can originate from any of these factors for any given project (Fig. 8). Thus, no single stakeholder group (engineers, seaports, regulators) is driving the decision.

The survey included a list of 14 barriers that may prevent SLC from being incorporated into design and asked respondents to select which barriers they have encountered in their career. The top 7 barriers contain a mix of project specific barriers and barriers that could be applied to all projects (Fig. 9).

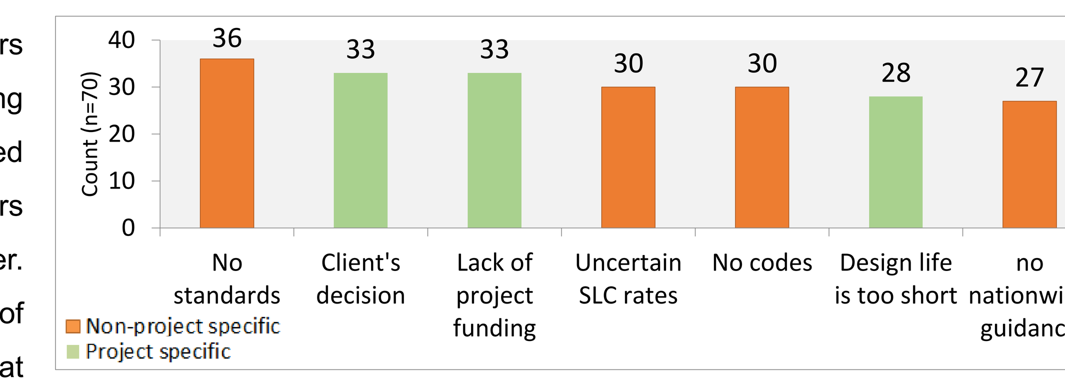


Figure 9. Top 7 potential reasons why SLC may not be incorporated into design

Results – RQ 3

Key Findings

- When SLC is not incorporated due to projects having too short of a design life, SLC uncertainty challenges are temporarily avoided, but incorporating SLC after initial construction during retrofit projects becomes more challenging

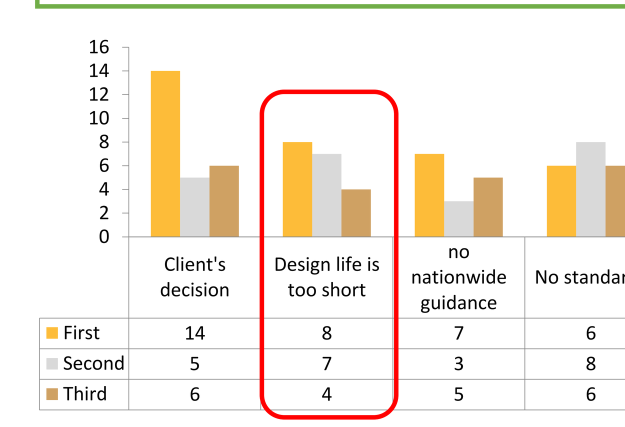


Figure 10. Top 4 barriers ranked as most common

Respondents were asked to identify the top three most common barriers to incorporating SLC (Fig. 10). After *Client's decisions*, the second most common barrier was *Design life is too short*. This finding suggest that projects with shorter design lives will not incorporate SLC, thus temporarily avoiding the challenges of SLC uncertainty in the future. However, since port structures can have long service lives, those structures likely will not be adequately designed for the sea levels toward the end of its service life. Furthermore, several respondents stated that incorporating SLC through retrofit, upgrade, or expansion projects.

Conclusion

The baseline data resulting from this research provides a first look at the state of the practice for designing port infrastructure for SLC. Findings highlight three main takeaways:

1. There is a need to develop regulatory design standards that engineers will follow to improve the resilience of port infrastructure. The development of such standards should involve a collaborative effort between engineers, port authorities, and regulators.
2. Due to the difficulties of incorporating SLC after initial construction through retrofit or upgrade projects, there is a pressing need to incorporate SLC for new infrastructure projects, rather than delay consideration until SLC projections become more certain.
3. Respondents indicated that a short design life is a primary reason why a project may not incorporate SLC. However, design life is a theoretical point in time, and port infrastructure can have much longer service lives. Therefore, engineers need to employ a life cycle cost analysis design approach more regularly to make more informed decisions on whether or not SLC should be incorporated into design.

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