Exploring Consensus to Develop Sea Level Rise Global Standards

Master Thesis

Zeeshan Jamadar

TU Delft

Exploring Consensus to Develop Global Standards in Response to Sea Level Rise (SLR)

Evaluating the Standardisation Scope of SLR Adaptation Using the Delphi Technique

Master thesis submitted to Delft University of Technology
in partial fulfillment of the requirements for the degree of

Master of Science

in

Engineering and Policy Analysis

Faculty of Technology, Policy and Management

by

Mohammed Zeeshan Shadahmed Jamadar

Student number: 5595207

To be defended in public on August 31st, 2023

Graduation Committee

Chairperson	: Prof.dr.mr.ir. Neelke Doorn	Ethics and Philosophy of Technology
First Supervisor	: Dr. Geerten van de Kaa	Economics of Technology and Innovation
Advisor	: Ir. Martijn Wiarda	Economics of Technology and Innovation

TU Delft Delft University of Technology

Exploring Consensus to Develop Global Standards in Response to Sea Level Rise (SLR)

Master Thesis

August 17, 2023

Acknowledgements

Exactly two years ago, I started my master's program in Engineering and Policy Analysis (EPA) at TU Delft. Back then, I was really grateful that a program like this even existed. I extend my heartfelt gratitude to the ingenious minds behind TU Delft for crafting this exceptional educational experience.

To my beloved parents, Shameem and Shadahmed, your unwavering support has been my cornerstone, shielding me from any form of pressure. Mom, your daily calls served as a reassuring embrace, ensuring my well-being. Dad, your steadfast trust and the freedom you granted me have been the bedrock of my achievements. I owe it all to both of you.

In this scholarly journey, I was fortunate to be guided by a thesis committee comprised of nurturing academics. To my advisor, Martijn, your mentorship has been the guiding light through every phase of my thesis. Your patient responses to my endless inquiries and insightful suggestions propelled me to delve deeper into the subject matter. Supervisor Geerten, your succinct feedback and thought-provoking inquiries consistently drove me to elevate my work. Chair Neelke, your unwavering support and encouragement bolstered my confidence, urging me closer to my thesis goals.

A select few individuals deserve special mention for making my academic voyage all the more delightful. Triveni, your unwavering assistance and selfless care were the pillars of my tranquility. Manjula, finding a steadfast friend like you in this master's program has been a true blessing. Aditya and Akash, the lighthearted conversations we shared were a constant source of joy.

To my peers and classmates, I extend my gratitude for embarking on this collective educational adventure. Your camaraderie, shared insights, and spirited discussions enriched my learning experience. While it is impossible to name each of you individually, please know that your collective support has been instrumental in shaping my academic path and the successful completion of this thesis.

Lastly, I must acknowledge the invaluable contributions of the knowledgeable participants in my study. Your insightful inputs and appreciative sentiments at various junctures of our interactions have indelibly shaped this thesis.

With profound appreciation,

Zeeshan Jamadar

“Simplicity is the essence of universality.”

■ **MAHATMA GANDHI**

Abstract

Anthropogenic climate change has led to irreversible Sea level rise (SLR), underscoring the urgency to implement adaptation measures. With there being a series of challenges to implement SLR adaptation, international standardisation emerges out to be a solution to address these challenges. In this research, an attempt is made to identify SLR adaptation measures that could be globally standardised using a consensus-based approach. The methodology for the research is a combination of desk-research and the Delphi method – involving rounds of surveys with an expert panel to reach consensus – that run a sequential manner. The research also aims at demonstrating the Delphi method as a cost-effective and time-saving method to develop adaptation standards. The research is able to develop a synthesis of a comprehensive list of adaptation measures that are in turn posed as the candidates to be standardised. A total of six adaptation measures attain consensus that include: (1) early warning systems, (2) seawalls, (3) levees, (4) sandbags, (5) dikes and (6) breakwaters. These adaptation options are chosen based on the identified meta-criteria developed as part of the results of the Delphi study. The meta-criteria is based on the reasons to develop an adaptation measure into standard and assesses three key themes that checks if an adaptation measure: (1) is a technical measure, (2) has a pre-existing methodology or standard that could be revised or newly drafted for SLR adaptation and (3) has a global data stream that could facilitate SLR based data sharing, collection and interoperability. These identified measures help in prioritising the adaptation measures that could be globally standardised. A key theme for the opposition of standardisation found in the literature and substantiated by the expert inputs is found to be of location-specific considerations for SLR adaptation implementation. Thus, to address such an apprehension of the panellists, the study makes crucial theoretical contribution to include an explanation to the relevance of standardisation to the challenges with SLR adaptation implementation. Furthermore, to propose and demonstrate the adoption of the Delphi method as a starting point to identify suitable options that could be standardised, the research develops an understanding of consensus in standardisation vis-'a-vis the Delphi method. The study's main limitations arise out of the limited numbers of rounds conducted that leave room for increasing the consensus levels for adaptation options as well as the missing interactions between the panellists that could have further added to the findings. Based on the findings the study provides three actionable policy recommendations to support the process of SLR international standardisation – (1) develop a consistent global language for SLR adaptation strategies and measures, including a classification of these measures, (2) raise awareness about the significance of standardisation in SLR adaptation among the world-wide community of stakeholders in this field, (3) establish a global platform for sharing appropriate SLR information usable across various adaptation measures. The study concludes with acknowledging that SLR adaptation global standards so developed need to be flexible and adaptive in order to incorporate location-specific considerations for each of the adaptation measures.

Keywords: Sea level rise; Climate change adaptation; Standards; Standardisation; Delphi method; Consensus

Contents

List of Figures

List of Tables

Acronyms

1. Introduction

Sea Level Rise (SLR) poses significant risks to coastal areas, representing one of the consequential impacts of climate change (IPCC 2018). Despite efforts to implement stringent climate change measures, SLR remains an inevitable outcome (Brown, Jenkins, et al. 2021; Houston 2013). Moreover, recent observations indicate that SLR is occurring at a faster pace than previously anticipated (Box et al. 2022). The implications for human civilization are substantial, with an estimated one billion people expected to face coastal-specific hazards by 2050 (IPCC 2022; Kumar et al. 2020). Consequently, SLR can be appropriately characterized as a global challenge, necessitating the widespread implementation of adaptation and mitigation strategies across the globe (Tribbia et al. 2008; Gibbs 2016).

Mitigation and adaptation are two viable approaches to addressing SLR. It is important to note that within the context of climate change policy, "mitigation" carries a distinct definition (UNISDR 2009). Specifically, mitigation refers to the reduction of greenhouse gas emissions and the enhancement of sinks, aiming to minimize climate change, including SLR, through climate policy interventions (R. J. Nicholls 2011). Whereas, coastal adaptation includes promising efforts, skills, techniques, plans, and technologies that might reduce the impacts of climate change and relevant coastal hazards. Thus, mitigation encompasses global-scale efforts tied to climate policy, while adaptation pertains to local-to-national activities connected to coastal management policy (R. J. Nicholls 2011).

Given the established inevitability of SLR, irrespective of the effectiveness of mitigation measures, it is prudent to prioritise adaptation without undermining the significance of mitigation efforts. Failure to implement adaptation measures would result in substantial annual flood damages amounting to nearly 4% of global GDP (approximately USD 50 trillion) in scenarios of higher-end SLR (1.3 meters) (OECD 2019). This would exert immense pressure on society's capacity to maintain an acceptable level of risk at a reasonable cost in coastal areas. Adopting coastal adaptation measures has the potential to significantly reduce costs; for instance, the implementation of coastal protection can curtail damage expenses by 2-3 orders of magnitude (OECD 2019). It is important to acknowledge that such remedies require substantial investments, potentially amounting to USD 70 billion by 2100 (OECD 2019). Moreover, coastal adaptation presents a unique challenge, as actions taken today carry long-term implications, while planning is conducted in the face of a highly uncertain future (OECD 2019).

The comprehensive range of adaptation strategies aimed at addressing SLR is encapsulated within the Protect, Accommodate and Retreat (PAR) model initially proposed by the Intergovernmental Panel on Climate Change (IPCC 1990). Over time, the PAR model has undergone evolution, incorporating advanced strategies and ecosystem-based adaptations (Oppenheimer et al. 2019). Each of these strategies encompasses a diverse array of adaptation measures, thereby complicating the selection process. Furthermore, despite the availability of various strategies for managing SLR, a significant concern arises from the heavy reliance on retreat as an option by numerous low-lying coastal areas in developing nations that can no longer afford to defend against SLR and coastal flooding. This reliance indicates a clear lack of proactive planning in SLR adaptations (Dedekorkut-Howes et al. 2020). Notably, these developing nations, despite contributing the least to the accumulation of atmospheric greenhouse gas concentrations, are projected to experience the most significant impacts (Donner et al. 2014). Consequently, there is an urgent and growing need for more comprehensive and proactive approaches to SLR adaptation (Dedekorkut-Howes et al. 2020).

Developing *international adaptation standards* can be seen as a proactive solution to address implementation of SLR adaptation. Such standards are developed in committees and are also known as de-jure standards (Wiegmann et al. 2017). A de-jure standard is "a document, *established by consensus* and approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" (CEN 2020; ISO 2020). A published de-jure standard is developed through cooperation and consensus in committees of Standard Development Organisations (SDOs) (Wiegmann et al. 2017; Goluchowicz et al. 2011). Herafter, in this study, the term standard and standardisation refer to de-jure standard and developing de-jure standards respectively. Instead of being the end point to a process, an established standard is a situation with a short-term equilibrium between the involved actors, i.e. where, for the time being, no actor attempts to challenge the status quo (Wiegmann et al. 2017). Thus,

a standard gives scope for reevaluation and updates – a handy property considering the evolving nature of climate change and the resultant SLR. By enabling a quicker and broader uptake of knowledge and best practices through an internationally recognised and trusted platform, standards can play a beneficial role in climate change adaptation (Lindner et al. 2021).

Numerous regions and governments have independently developed frameworks, guidelines, and technical design documents as part of their efforts to address SLR adaptation. These resources take the form of handbooks, engineering manuals, or national standards (see Beavers et al. 2016, USACE n.d., PBC 2021, UNDP 2019). However, there is still a lack of exploration regarding the possibility of global standardisation for SLR adaptation measures. Global SLR adaptation standards would encompass a comprehensive set of rules and guidelines for adaptation measures, including but not limited to risk assessments, evaluation and monitoring systems, and technical designs of adaptation measures. Several studies have highlighted the necessity of standardisation for flood protection (Gilman et al. 2008; Lal et al. 2012; Kumar et al. 2020). The establishment of global adaptation standards could facilitate cross-national harmonization, as advocated by prominent organizations such as the European Union (EU) and the World Trade Organisation (WTO) (de Vries et al. 2017).

With rapidly rising sea levels, there is an urgent need to develop global adaptation standards in response to sea level rise. The conventional approach to developing standards by international organisations such as International Organisation for Standardisation (ISO) is expensive and time-consuming, taking up to 48 months to yield results (Farrell et al. 2012). Therefore, it is prudent to take up a similar yet efficient method to explore the global standardisation scope of SLR adaptation options. One such option is the Delphi method, that also relies on achieving consensus within the expert panels in rounds of surveys (Hsu et al. 2007), much-like the standardisation processes. As understood, there are is a multitude of adaptation options and forming technical standardisation committees for each of these without evaluating their suitability to be developed into a standard would be time-consuming. The Delphi method could potentially address this concern by prioritising adaptation measures for global standardisation in a cost-effective and time-saving manner. This study makes use of the Delphi method to identify SLR adaptation measures that could be globally standardised.

1.1. Research objectives and research questions

There is a multitude of adaptation measures available to tackle SLR (Dedekorkut-Howes et al. 2020). The development of global standards for these adaptation measures would require consensus of the relevant stakeholders. As established, this is yet to be explored. Thus, the objective of the research is to explore consensus on SLR adaptation measures that could be globally standardised. The main research question for the study is:

"What areas of Sea Level Rise (SLR) adaptation measures could be globally standardised?"

The term "areas" in the above main question means the various adaptation measures including but not limited to risk assessments, evaluation and monitoring systems, and technical designs of adaptation measures. The global adaptation standards will incorporate any of the aforementioned set of areas at an international scale. The main research question is answered by addressing the following sub-questions (SQs) in a sequential manner. At the same time, these sub-questions while arriving at their own results, will also serve as an assessment of the Delphi method to be used in standards development process.

1. What are the available adaptation measures against SLR?
2. What SLR adaptation measures have the highest potential to be globally standardised?
3. Why these SLR adaptation measures could be standardised?

1.2. Report organisation

Section 2 presents a literature review that contains an overview of available SLR adaptation measures and issues with SLR adaptations. Section 3 contains the methodology that explains the research design and the Delphi method. Section 4 showcases the results of round 1 and round 2 of the Delphi study, followed by the discussion in Section 5. Lastly, Section 6 contains the conclusion of the research.

2. Literature review

In this section, a review of available SLR adaptation measures is presented by following a classification based approach identified in the literature. This review is built using the reviews from Dedekorkut-Howes et al. (2020) and Oppenheimer et al. (2019). Furthermore, the issues pertaining to SLR adaptation are identified using a systematic literature review. Consequently, this review supports in highlighting the main challenges associated with SLR and the relevance of standardisation with regards to addressing these challenges is provided.

2.1. Adaptation measures for SLR

The *Protect, Accommodate and Retreat (PAR) model* forms the backbone of the categorisation of SLR adaptation methods (IPCC 1990). However, there have been several debates around what constitutes SLR adaptation strategy, for instance – Adger et al. (2009) consider only two strategies to reduce the impact of natural hazards and SLR: (1) rebuild/fortify threatened infrastructure and (2) strategic retreat. Nonetheless, recent advancements in this field has led to an evolution of this model. The model now also encapsulates, *Advance* and *Ecosystem-based Adaptation (EbA)* (Oppenheimer et al. 2019). The basic mechanism behind these adaptation strategies given by Oppenheimer et al. (2019) is shown in figure 2.1.

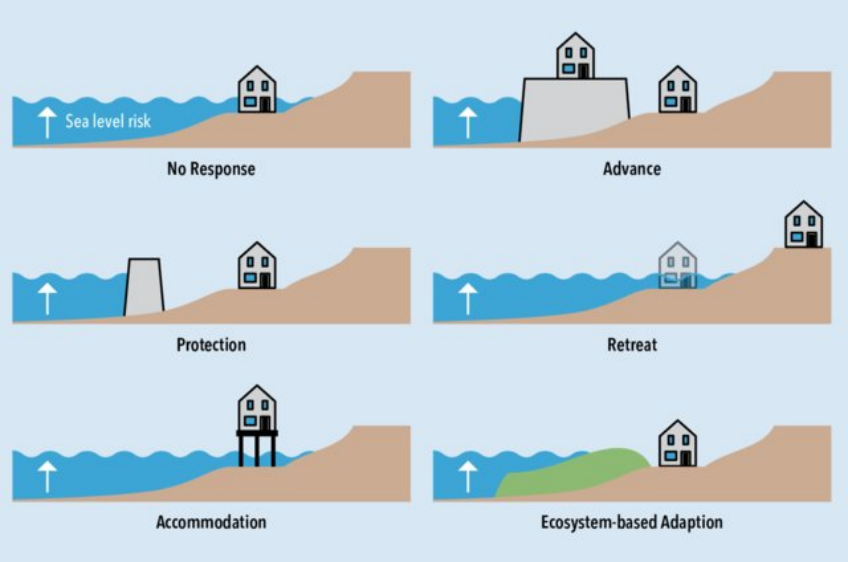


Figure 2.1.: Different types of responses to coastal risk and sea level rise (Oppenheimer et al. 2019)

The *protection* strategy is based on the defence of vulnerable areas where population, built assets, economic activity, and natural resources are located by decreasing the impacts of a negative event. *Accommodation* involves the continued use of vulnerable areas while enhancing the capacity of the population and the natural and built environment to cope with impacts. *Retreat* requires the "abandonment of land and structures in vulnerable areas and re-settlements of inhabitants" (IPCC 1990, p. 146). As a result, *retreat* reduces coastal risk by removing vulnerable people, assets, and human activities from the coastal hazard zone (Oppenheimer et al. 2019). Furthermore, there is a fourth debatable option of *attack* which involves "advancing the line" of resilient development seaward (Dedekorkut-Howes et al. 2020). By expanding seaward, *advance* generates fresh land while lowering coastal dangers for the hinterland and newly elevated land. For instance, land reclamation above sea level by filling with pumped sand or other fill material, planting vegetation with the specific intention of supporting natural accretion of land, and surrounding low areas with dikes (a process known as polderisation), which

also necessitates drainage and, in some cases, pumping systems (Oppenheimer et al. 2019). Lastly, we have *Ecosystem-based Adaptation (EbA)* that provide a combination of protect and advance benefits based on the sustainable management, conservation and restoration of ecosystems (Alverson 2012). Examples include the conservation or restoration of coastal ecosystems such as wetlands and reefs. EbA is also referred to by various other names, including Natural and Nature-based Features, Nature-based Solutions, Ecological Engineering, Ecosystem-based Disaster Risk Reduction or Green Infrastructure (Oppenheimer et al. 2019).

The boundaries between these strategies are blurred, and there is substantial overlap in their conceptualizations. What one researcher regards as accommodation, another may regard as protection. So, Dedekorkut-Howes et al. (2020) provide a classification of the well-known adaptation measures (see Figure 2.2). As a result, land reclamation is mentioned in all four key strategies.

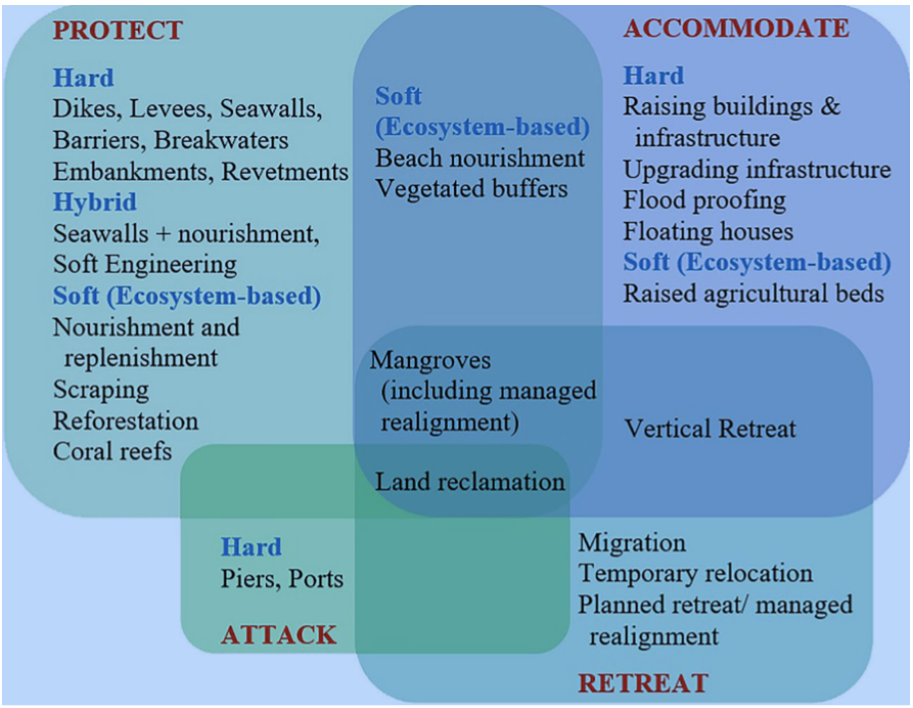


Figure 2.2.: Classification of adaptive responses based on adaptation strategies (Dedekorkut-Howes et al. 2020)

The popular strategies adopted in the planning for SLR protection revolve around protection and accommodation methods (Dedekorkut-Howes et al. 2020; Adger et al. 2009; Bowering 2014). However, in practice, i.e. when it comes to actual implementation, especially among those nations who cannot afford huge investments, it is the strategy of retreat that is frequently employed (McNamee et al. 2014; Dedekorkut-Howes et al. 2020). Based on their physical characteristics, these adaptation strategies can be broadly categorised into four varieties (Dedekorkut-Howes et al. 2020):

1. Structural: Consists of both, hard structural and ecosystem based options. The former relies on engineering/infrastructural developments while the latter is more inclined towards nature-based adaptation by employing mangroves, coral reefs, estuaries and other systems near the shorelines.
2. Non-structural: These involve use of knowledge, practice or agreement to reduce risks and impacts (UNISDR 2009).
3. Retreat: These involve shifting away from the affected coastlines. The strategy involves planned permanent retreat and migration or temporary retreat relocation.
4. Integrated: It is a combination of two or more of the PAR model options that seeks to create win-win situations for adaptation to SLR in long-term while solving current problems (R. J. Nicholls 2011).

A large set of adaptation measures exists under all these above categories as shown in Figure 2.2. All these have their relative advantages and disadvantages (Dedekorkut-Howes et al. 2020). On one hand, such a variety gives a wider range of options to choose from; on the other, it makes it complicated to choose the best option or to prioritize one technique over other. By combining the inputs from strategy

classification by Oppenheimer et al. (2019) and the SLR adaptation techniques review done using their strategy and physical characteristics by Dedekorkut-Howes et al. (2020), the following Table 2.1 below presents a comprehensive overview of SLR adaptation measures.

Table 2.1.: Adaptation measures overview

Strategy and *Measure Type*	Measure	Definition/Activities/Processes of the Adaptation measure
Protect		
Hard structural: Man-made structures to block water	Sea walls	Structure, often concrete or stone, built along a portion of a coast to prevent erosion and other damage by wave action. Usually, it retains earth against its shoreward face. It often consists of sloping concrete construction that might be flat, stepped, or curved in appearance. A seawall can also be constructed as a rubble mound, a block seawall, a steel or timber construction. The common feature is that the structure is built to resist high wave action and storm surge.
	Dikes	Dike is a Dutch word that originally meant the bank of a body of water. Dikes are "earth structure along sea or river in order to protect low lands from flooding by high water" (USACE 2003, A23). When used with active pumping and drainage, dikes can be very effective in preventing coastal flooding.
	Groynes or Groins	Groynes are "narrow, roughly shore-normal structure built to reduce longshore currents, and/or to trap and retain littoral material. Most groins are of timber or rock and extend from a seawall, or the backshore, well onto the foreshore and rarely even further offshore" (USACE 2003, A34). Their design depletes the sand supply to the beach area immediately down-drift of the structure. In response, down-drift property managers often install groins on adjacent properties to counteract the increased erosion, leading to a cascading effect of groin installation.
	Leeves	Levees are a type of "large dike or artificial embankment, often having an access road along the top, which is designed as part of a system to protect land from floods" (USACE 2003, A44).
	Breakwater	"A structure protecting a shore area, harbor, anchorage, or basin from waves." (Linares 2012, p. 1). It is a member of the Water Barrier group of structures in coastal engineering, and it can describe a system when many breakwaters and functions are combined as a package. A breakwater's aim is to diffract, disrupt, and block the continuity of an oncoming wave in order to produce a calm or shadow zone with little or no wave activity behind it.

Strategy and *Measure Type*	Measure	Definition/Activities/Processes of the Adaptation measure
	Storm surge gates/ flood barriers	Storm surge gates / flood barriers are "fixed installations that allow water to pass in normal conditions and have gates or bulkheads that can be closed against storm surges or spring tides to prevent flooding. They can close the sea mouth of a river or waterway. These barriers can be major infrastructure systems involving significant costs for construction and are often linked with other flood protection measures, such dikes, seawalls and beach nourishment. Storm surge barriers are normally used to protect urban settlements and infrastructure heavily affected by storm surges and sea flooding." (Climate-ADAPT 2023b)
	Gabions	Gabions are prefabricated building blocks made of wire mesh that are filled on-site with gravel, stone or crushed concrete. They are filled on-site, sometimes with locally accessible materials, and are an effective and relatively low-cost capital investment. Because they are porous and flexible, they can absorb some wave and wind energy, lessening the erosion difficulties associated with impermeable sea defences such as concrete seawalls (UK 2021).
	Jetties and Piers	A jetty is a narrow, long structure that guards a coastline against currents and tides. Jetties are typically constructed of wood, earth, stone, or concrete. They extend from the beach into the water. Jetties can also be utilised to connect the land to deep water further out from the beach for docking ships and unloading cargo. This type of jetty is called a pier.
	Sandbags	Bags filled with sand, usually made of jute, are stacked and arranged along the eroding coast to form embankments to keep water out of built up areas. However, because this practise fosters sand mining, which increases erosion, it must be monitored (Musa et al. 2016).
Soft: Ecosystem-based barriers for water	Wetlands	Coastal wetlands (or tidal marshes) are saltwater and brackish water wetlands located in coastal areas. They provide natural defence against coastal flooding and storm surges by wave energy dissipation and erosion reduction, helping to stabilise shore sediments. There are two primary management options to implement this measure: raise the elevation of drowned areas by creating/restoring new wetlands, or insure that replacement wetlands can form as inundation occurs through a process of managed retreat. Additionally, options to defer action and the combine approaches can be explored as well (Climate-ADAPT 2023a).

Strategy and *Measure Type*	Measure	Definition/Activities/Processes of the Adaptation measure
	Mangroves	Mangroves are tropical trees with interlacing prop roots, confined to low- lying brackish areas. The approach involves protection, restoration, and/or sustainable management of mangrove forests. These forests protect the shoreline and communities from storm surges, tsunamis, and sea level rise, and they are an excellent example of a no regrets solution providing multiple benefits (Alverson 2012).
Human interventions to enhance capacity of natural barriers	Beach nourishment	The IPCC (1990, p. 150) describes beach nourishment as the action of "dredging sand from back bays, navigation channels, or offshore, or excavating material from a land-based source and placing it on the beach". Beach nourishment is also defined as "the process of mechanically or hydraulically placing sand directly on an eroding shore to restore or form, and subsequently maintain, an adequate protective or desired recreational beach " (Linares 2012).
	Dune restoration	Dune restoration or dune building is another type of "soft" structure approach that helps natural dunes recover from de-stabilizing forces. This restoration process "involves rebuilding sand dunes where they have been eliminated, increasing their area size dependent on the amount of space available, and allowing natural process to rework them into topographically diverse landforms with a variety of habitats" (Nordstrom 2008, p. 49).
Accommodate		
Hard structural:Design interventions into the built environment and infrastructure	Elevating buildings and infrastructure, flood proofing	This involves physical construction of or around the existing structures such as elevating the building, raising the floor levels or combining these together (Harwitasari et al. 2011).
	Upgrading drainage and stormwater systems	It's a network of structures, channels and underground pipes that carry stormwater (rain water) to ponds, lakes, streams and rivers. The drainage and stormwater upgrade systems incorporate (1) enhanced gravity drainage (using large pipes or drainage channels) and (2) forced drainage (using larger pumps) (Titus et al. 1987).
Soft: Ecosystem-based approaches to cope with impacts	Land reclamation	Implies that the land that once belonged to the sea, or where a wetland was drained to form a drier area of land, and subsequently protected, such as by a dike (Brown, Wadey, et al. 2020).
	Vegetated buffers	Vegetated buffers are "continuous areas of vegetation bordering streams or wetlands, separating them from surrounding land uses" (Myszewski et al. 2014, p. 1). Vegetated buffers are measured from the upland/wetland boundary rather than the water's edge. Creating a buffer from this point helps to keep possible contaminants out of wetlands while also protecting them from development impacts including filling, grading, and sediment flow (Myszewski et al. 2014).

Strategy and *Measure Type*	Measure	Definition/Activities/Processes of the Adaptation measure
Retreat		
Horizontal planned retreat: Phased relocation of highly vulnerable structures	Lateral relocation of assets and communities	The managed/planned abandonment of low-lying high risk areas is related to the use of wide setback restrictions that provide a buffer zone between development and the coast (Dedekorkut-Howes et al. 2020).
Migration	Permanent abandonment of an area	Also termed as 'adaptive migration' which includes a broad range of actions, including proactively moving out of an area of risk exposure (Martin et al. 2017).
Temporary relocation: Moving to higher land during floods	Short term relocation during natural hazards	Involves allowing temporary evacuation options, especially for island and delta communities (Laurice Jamero et al. 2017). Temporary relocation allows communities to retain temporary houses on the low-lying areas (i.e. islands) for their livelihood, while using permanent houses on the relocated areas during natural hazards (Dedekorkut-Howes et al. 2020).
Non-Structural Strategies		
Policy regulation: Use of regulatory institutional tools to deal with the impacts of coastal flooding and SLR	Coastal management, integrated coastal zone management	To regulate the natural environment to accommodate the impacts of SLR and coastal flooding through the maintenance and protection of important ecosystems, the regulated use of ecologically risky zones, and the designation of retention and infiltration areas. Incorporating climate change and SLR into the planning process can involve the use of policy tools such as the requirement for freeboards (height of the watertight portion of a structure), setbacks, and changes to land use zoning regulations.
Community capacity building: Promoting the capacity of local communities to develop and sustain their own adaptation	Learning, engagement, raising awareness, incorporating indigenous knowledge	Improving community capacity comprises strategies that promote social learning, raise awareness, enhance community outreach and involvement, and create financial capacity through instruments like cost sharing/insurance (Marshall et al. 2014).
Disaster Risk Reduction: Efforts to reduce the impacts of disasters and vulnerability of communities	Monitoring and early warning systems	Early warning systems have been broadly defined by UNISDR (2009) as "the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response." (Denamiel et al. 2021) Short-term forecasts (typically up to 7 days) produced by an Early Warning System (EWS) allow local authorities to issue timely warnings and to coordinate preparedness and evacuation measures, which ultimately reduces risk to lives and assets. (Winter et al. 2020)
	Hazard and vulnerability assessment	Involves mapping for identification of areas exposed to sea level rise under different scenarios (Dedekorkut-Howes et al. 2020).

Strategy and *Measure Type*	Measure	Definition/Activities/Processes of the Adaptation measure
Governance: Institutional frameworks within which decisions regarding adaptation are made	Adaptive management and governance	Includes institutional capacity building and integration between different actors at different levels of governance, stakeholder engagement in decision making processes, and processes that support the co-generation of knowledge. This method is based on effective stakeholder participation and collective decision making at various levels.(Lawrence et al. 2015).
Integrated Strategies		
Combination of protection, accommodation, and retreat; or structural and non-structural measures	For instance: Construction of seawalls and relocation of some areas	Combining the protect and retreat strategies.

The option of retreat can be further classified into preemptive (systematic relocation of communities) and reactionary (adopted when the levels of SLR become unacceptable). The latter is the most resorted to (Gibbs 2016), indicating that there needs to be more successful planning involved regarding protection against SLR. However, the retreat option cannot still be discarded entirely. Even after resorting to best-management practices in flood management, the continual SLR would force the responsible authorities to relocate entire neighbourhoods and rebuild large infrastructures (Pinto et al. 2018). The hindrance to uptake of the retreat adaptation strategy is the lack of consideration of political risk (Gibbs 2016). That is why these adaptation options are known as "tough sell," as it would only be possible to quickly implement them when the actual costs of defending in place (such as increasing insurance premiums and escalating costs of building defences) become evident (Pinto et al. 2018).

For those areas that do not have a place to retreat, Community-based Adaptation (CBA) is practised as a last resort (Jamero et al. 2018). Cases of CBA include island communities that are, at times, completely inundated during high tides. Such responses are bottom-up approach"autonomous" measures unlike the planned top-down governmental measures (Jamero et al. 2018). However, CBA cannot be a long-term solution. It requires sufficient financial resources and proper technical consideration. Nevertheless, CBA indicates that the adaptive capacity of SLR-exposed communities is far higher than anticipated.

2.2. Issues with current SLR adaptation strategies

The following Table 2.2 gives an overview of articles that highlight the major issues associated with SLR adaptations. The articles used in Table 2.2 are discovered through the Scopus portal and snowballing. The key words associated with the research being "Standardisation" and "Climate change" posed a problem due to the way in which they are used in various academic papers (Leal et al. 2022) and gave a search result pool of over 29,000 articles. The search was performed using the search query as: "sea level rise" AND ("adaptation" OR "measures") AND "flood*" (to include all the terms such as flooding or floods) AND ("standard*" OR "best practices"). Further, the articles from Chinese language and the field of medicine were excluded as they would prove not to be comprehensible and relevant respectively. This brought down the number of articles to a manageable number of 52. The articles used in this review have been selected from these 52 articles by reading their abstracts and choosing those that have higher policy relevance to SLR adaptations – terms such as "national", "overview" and "policy" helped in filtering out these articles. The column "Regional Aggregation Level" provides insights on the regional level at which the study was conducted. For instance, the study by Sharaan et al. (2022) explains Egypt's SLR coastal adaptation practices and hence the regional aggregation mentioned is "National". Some additional insights that explain interlinking between few of these studies are covered below the table.

Table 2.2.: Literature overview of issues with SLR adaptation

Article	Focus	Regional Aggregation Level	Key Recommendations/Findings
Sharaan et al. (2022)	Overview of Egypt's coastal adaptation against SLR	National	•Protection strategy is the most effective. •Improve coordination between researchers and decision makers
Colgan et al. (2022)	Policy insights on local level SLR to resolve national level SLR	Local to National	•Need of an overarching common national sea-level adaptation plan •Continual need for updating sea-level projections in an understandable manner for the stakeholders
R. Nicholls et al. (1996)	SLR vulnerability assessment of Mediterranean sea region for SLR adaptations	Cross-National	•Need of low-cost and highly flexible measures that cater to full range of likely scenarios
Houston (2013)	Use of probability based assessment to design SLR adaptations	Global	•Use of statistics of Sea level projections to design flood projects instead of using maximum possible SLR
Hall et al. (2019)	Support decision-making by advancing the SLR scenario methods	National	•Increase coproduction between scientists and decision-makers •Careful selection of probabilities
Tiggeloven et al. (2020)	Provide benefit-cost analysis of structural coastal adaptation measures	Global	•SLR contributes to more than 50% of the total climate adaptation costs
Lorie et al. (2020)	Advancing US's National Coastal Property Model (NCPM) for simulating adaptations decisions	Local	•Adaptation decisions cannot solely be based on benefit-cost analysis
Pinto et al. (2018)	Assess the existing institutional arrangements for designing coastal adaptations techniques	National	•Adopting uniform procedures among all the institutions from local to national level for SLR adaptations •Improve communication between stakeholders to avoid implementation that caters to narrow mandates
Jamero et al. (2018)	Analyse Community Based Adaptation (CBA) against SLR in the Philippines Islands	Local	•Community participation can enhance the resilience of planned adaptation measures •Need of additional funding and technical support for increasing climate resilience of CBA strategies
Jonkman et al. (2018)	Assess risk and reliability of existing SLR adaptation hydraulic infrastructure in the Netherlands	National	•The implemented standards and infrastructure for flood defense in the Netherlands have become outdated •Derived new national safety standard for flood defences

Article	Focus	Regional Aggregation Level	Key Recommendations/Findings
Cozannet et al. (2017)	Requirements for effective use of SLR information in coastal climate services (CCS)	Global	•Establishing a global framework for CCS •Develop a standard in the area of CCS supporting adaptation to climate change
Johnston et al. (2014)	Identify parameters to develop a method of prioritising key infrastructures for SLR adaptations	Local	•The adaptation options need to incorporate location-specific, systemic and broad strategic solutions
Dedekorkut-Howes et al. (2020)	Literature review of SLR adaptation responses	Global	•Need of integration of uncertainty within strategic planning to counter long-term SLR threat
Gibbs (2016)	Identify political risk of coastal adaptation pathways	Global	•The political approach to coastal adaptation yields short-term solutions since it yields higher incentives to the politicians
Tribbia et al. (2008)	Identify information needs of SLR coastal adaptations	Local	•Improving transfer and uptake of relevant scientific information with the help intermediary boundary organisation

Proper Coastal management requires adequate information (Tribbia et al. 2008). The type of information include environmental features, socioeconomic information and geological information - all these information needs are not met. In addition, there is another concern about the lack of information understanding, as the risks need to be communicated to the coastal dwellers (Lorie et al. 2020). Thus, defining the process of the transfer and uptake of relevant scientific information becomes a potential area to address. A global framework for Coastal Climate Services (CCS) is a promising solution (Cozannet et al. 2017). CCS include the provision of research data, information and translation of climate research into an operational delivery of services in support of adaptation of climate change (Cozannet et al. 2017).

Colgan et al. (2022), Sharaan et al. (2022) and Melville-Rea et al. (2021) in their study of Denmark, Egypt and the United Arab Emirates (UAE), respectively, highlight the need for location-specific solutions and adaptation strategies. However, a crucial limitation of this local approach is that each of the municipalities, has varying risk management and adaptation actions while having similar coastal geomorphology and coastal processes (Sharaan et al. 2022). Unsurprisingly, there is a growing consensus on increasing coordination between various levels of government and other stakeholders for adaptation responses (Hall et al. 2019; Pinto et al. 2018; Jamero et al. 2018).

Challenges with SLR adaptation and relevance of standardisation

Based on the above literature overview of issues with SLR adaptation, the main challenges within the area of SLR adaptation have been identified. Furthermore, for each of the challenge the relevance of standardisation is presented in the Table 2.3.

Table 2.3.: Challenges with SLR adaptation

Sr. No.	Challenge	Articles	Standardisation relevance
1.	Lack of agreement on classification and definitions of SLR adaptation measures	Dedekorkut-Howes et al. (2020) and Adger et al. (2009)	Develop common language i.e. consistent terminology (CEN 2020)

Sr. No.	Challenge	Articles	Standardisation relevance
2.	Inefficient coordination and communication between stakeholders of SLR adaptation	Gibbs (2016), Pinto et al. (2018), Hall et al. (2019), Sharaan et al. (2022), and Box et al. (2022)	Follow inclusive and consensus-based approach enhancing linkages between multilateral commitments (CEN 2020; ISO 2020)
3.	Inaccessibility and unavailability of right set of SLR information	Tribbia et al. (2008), Cozannet et al. (2017), and Lorie et al. (2020)	Promote technical connectivity, interoperability and sustainability of information (Dora 2018)
4.	Outdated and unsuitable SLR adaptation standards and methodology	Johnston et al. (2014) and Jonkman et al. (2018)	Provide scope for revision to stay up-to-date with the state of the art technology (CEN 2020)
5.	Lack of funding and high cost of implementing SLR adaptation	R. Nicholls et al. (1996), Jamero et al. (2018), Tiggeloven et al. (2020), and Lorie et al. (2020)	Reduce cost by reducing parallel efforts in research, design and maintenance processes (Ware et al. 2020; CEN 2020)

Standardisation has the potential to address the SLR adaptation challenges and it is likely to yield increased future socio-economic benefits (Goluchowicz et al. 2011). The basic characteristics of standards demonstrate the importance of standardisation in SLR adaptation. Standards can define a common language for products, processes, and phenomena. Misuse of specific terms and misunderstandings can be avoided in this manner. Key terms are defined clearly, creating legal certainty in areas such as the definitions of SLR adaptation measures. Standards can also define methodologies that ensure the comparability of measurement results, allowing for, for example, environmental monitoring (CEN 2020). The common language and consensus-based approach help in fostering efficient communication of information and improved coordination amongst the stakeholders (Dora 2018). Furthermore, standards are regularly updated in accordance with standardisation rules when new technological developments come-up. This helps governments and other administrative bodies' regulations to remain compatible with the 'state of the art' by referring to these standards (CEN 2020). Simultaneously, by actively monitoring standardisation developments or actively participating in standards committees, the public sector keeps up with the latest developments, allowing for better design of research and innovation programmes (such as using Nature based solutions) (R. J. Nicholls 2011). Such proactive steps lead to increased effectiveness of the option under consideration to be standardised and reduces overall costs by eliminating parallel efforts (Ware et al. 2020). Lastly, we see that very few studies have addressed the global nature of SLR and most of the studies either focus on the local or the national level of aggregation. As SLR impacts extensive areas, it is prudent to take broader planning approaches (Johnston et al. 2014; R. Nicholls et al. 1996), that could well be addressed by international standards.

However, it is also necessary to acknowledge that there is no one-size-fits-all solution to the problem SLR adaptation (Dedekorkut-Howes et al. 2020). The standards so developed need to incorporate location-specific, systemic and broad strategic solution (Johnston et al. 2014). It is, therefore, important that the standards be developed such that they (1) allow for site-specific approaches and localised interpretations, (2) utilise the best-available scientific understanding of relevant climate change risks, impacts, and vulnerabilities, (3) has elements of adaptive design to incorporate future climate change scenarios and (4) enable strong partnerships amongst stakeholders (CEN 2022).

With this, we have now seen the major aspects of SLR – the popular adaptation measures under various strategies, associated issues and challenges with adaptation and the relevance of standardisation. The next section is methodology that covers the overall research design.

3. Methodology

This section contains the strategy and methods that are used in the research. The strategy and methods are largely dependent on the sub-questions (SQs) and will thus roughly follow the same structure to improve understanding and readability.

3.1. Research methods and research flow diagram

Creating a standardisation committee requires a qualitative research approach. This study explores to provide initial directions for future efforts – specifically, to identify potential sea-level rise (SLR) adaptation measures suitable for consensus-based standardisation. Figure 3.1 outlines the research process and methods for each sub-question (SQ), with step-by-step answers for each SQ.

Desk research tackles sub-question 1 (SQ1) in Section 2.1, discussing overall SLR adaptation strategies and related measures. These measures were derived from reviews by Dedekorkut-Howes et al. (2020) and Oppenheimer et al. (2019). The insights from SQ1 serve as a basis for addressing SQ2 and SQ3, which employ the Delphi method explained in Section 3.2 below.

3.2. The Delphi method

Standards materialise through consensus and gain validation from recognized bodies, such as National Standardisation Organisations (NSBs) (Furman et al. 2002). Similarly, akin to the process of standardisation, the Delphi method hinges upon expert consensus (Hsu et al. 2007). Devised by Dalkey et al. (1963) at the Rand Corporation during the 1950s, the Delphi method stands as a widely acknowledged approach for soliciting consensus-driven insights from experts within specific subject domains. Employing a sequence of surveys, this technique captures input from a selectively chosen panel of participants (Dalkey et al. 1963; Hsu et al. 2007). Its utility extends to informing prospective decision-making, strategic planning, and policy assessment (Gordon et al. 2006). Furthermore, the Delphi method facilitates accessing costly or inaccessible information, addressing complexities, and synthesizing fragmented knowledge for a shared understanding (Sourani et al. 2014). The technique's value extends beyond consensus-yielding studies, encompassing those without consensus and generating valuable insights into extreme viewpoints (Gordon et al. 2006).

The method exhibits substantial parallels with the standardisation process as explained in Table 3.1. Consequently, it finds application in various standardisation-related studies (e.g., Goluchowicz et al. (2011), Breugel (2022), and Utmani (2021)). However, unlike standard development procedures, Delphi surveys lack interactive committee group discussions (Goluchowicz et al. 2011).

Table 3.1.: Similarities between standardisation processes and Delphi surveys (Goluchowicz et al. 2011)

	Delphi Survey	Standardisation Process
Stakeholder	•adaptable for a heterogeneous circle of respondents	•involvement of heterogeneous stakeholders
Process	•multi-stage assessment and coordination process	•long-lasting multi-stage coordination process
Result	•setting priorities •aiming on consensual results •dependent on the involved experts	•setting priorities •decision-making by consensus •dependent on the involved stakeholders

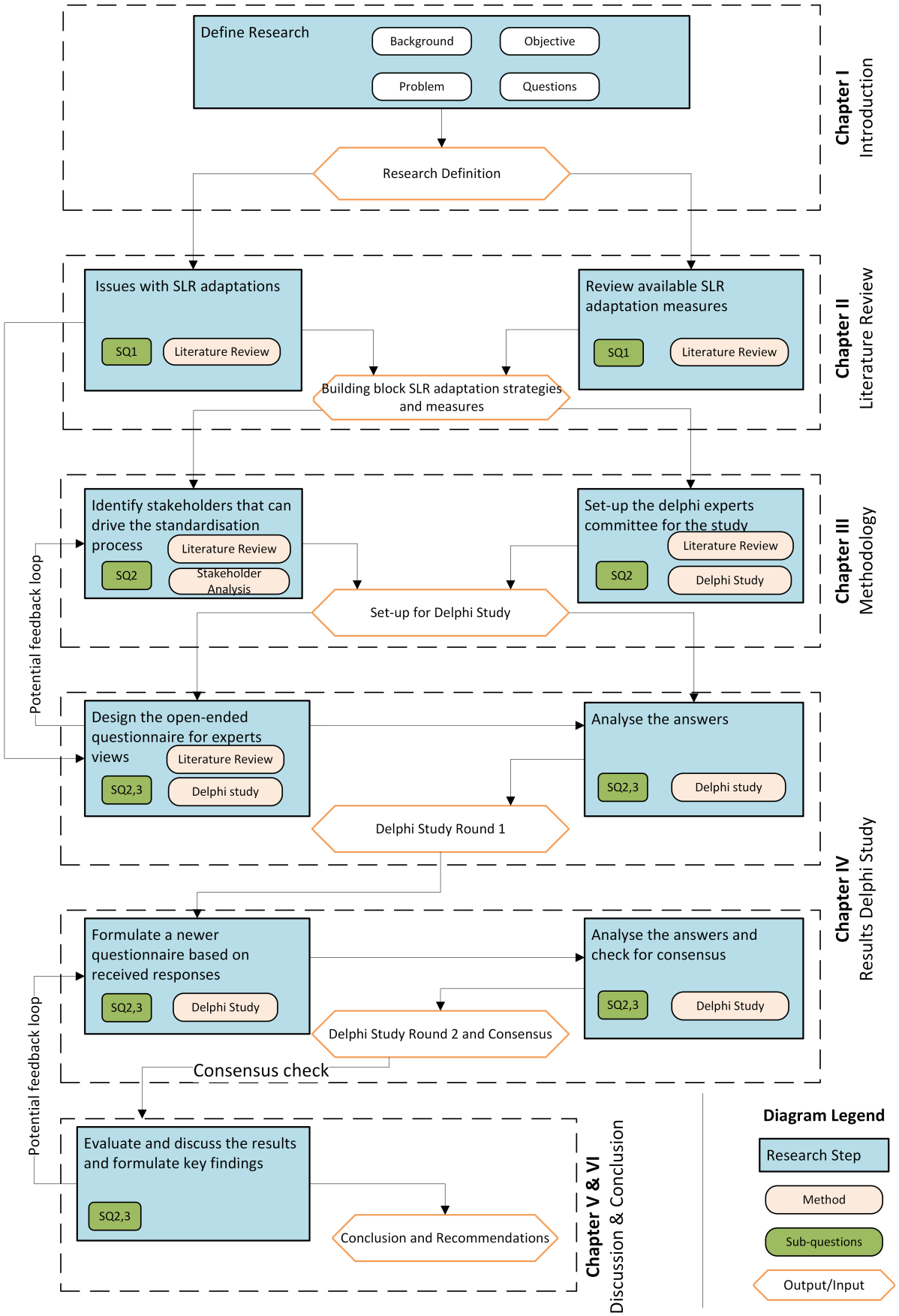


Figure 3.1.: Research flow diagram

Thus, with all its characteristics and similarities with the standardisation process itself, the Delphi method was used in the study for the subsequent sub-questions (SQ2 and SQ3). The study was conducted in rounds that contain a series of steps that more or less remain the same, the overview of these steps is shown in Figure 3.1. As outlined, the Delphi study presented here consisted of two rounds of online surveys, starting with an open qualitative round that was used to identify options that were then narrowed down and quantified in the second round. A crucial criteria to achieve the results of the study is based on consensus levels. The consideration of the consensus levels is covered in Section 3.4.5 as it is also based on the composition of the Delphi panel. The following sub-sections describe the main steps of the study and other key considerations.

3.3. Preparation and ethical approval (April–May 2023)

This step included internally drafting, evaluating, and deciding on a Delphi research protocol to verify that questions are appropriate and clear to external participants. The questionnaire was developed based the theoretical output of the SQ1. Each of the Delphi survey instrument was evaluated for comprehensibility and usability. This was accomplished by first distributing the survey to the thesis committee and collecting feedback.

The study was awarded ethical approval in April 2023, by the Human Research Ethics Committee (HREC) of Delft University of Technology, the Netherlands. A condition of ethics approval was that no personal data was to be shared publicly or with the participants. Responses were to be analysed anonymously. Furthermore, it is only after the HREC approval that experts could be contacted to participate in the research. All the HREC approval documents associated with the study are in the Appendix A.

3.3.1. Expert panel formulation

The sampling strategy for data collection from experts in standardisation requires a stakeholder identification (Goluchowicz et al. 2011). The literature has established that one of the main barriers to efficient SLR adaptation planning include a lack of large-scale coordination between various stakeholders (Pinto et al. 2018; Hall et al. 2019; Stephens et al. 2020). Stakeholder participation is increasingly considered as an essential component of water-related policy making, both as a means of democratisation and of improving decision making (Doorn 2016). Thus, to formulate an expert panel a stakeholder identification is presented in the following sub-section.

Stakeholder identification

The stakeholder identification is based on the climate governance model proposed by Hoffmann (2011) which in turn is applied to governance experiments in water management by Doorn (2016). Thus, the choice of stakeholder groups is based on the notion if these perform one or more of networking, planning, direct action and/or oversight functions (Hoffmann 2011; Doorn 2016). Thus, the government actors emerge as the starting point as these serve all these functions. However, successful adaptation not only depends on governments but also on the active and sustained engagement of other stakeholders, including local communities, national, regional, multilateral and international organisations, public and private sectors, civil society and other relevant actors, as well as an effective management of knowledge (UNFCCC 2022). Table 3.2 below contains these stakeholder groups along with their roles in relation to SLR adaptation.

Table 3.2.: Stakeholders identification

Stakeholder group	Role in SLR adaptation
Government sector	The implementation of policies and adaptation measures against SLR, being in a public domain, mainly falls under the realm of respective government authorities of various regions (Vegh et al. 2022). As a consequence, a diverse set of government representatives from coastal planning and protection authorities is set as the starting point to identify individuals for the panel. A range of governmental bodies are available in different countries that have diverse functions as per their respective legal frameworks and governance models. For instance, consider India and the Netherlands. India, with one of the longest coastlines, has a two-fold division of coastal management responsibilities. Firstly, the federal Ministry of Water's (Jal Shakti) Central Water Commission (CWC) designs coastal protection measures and prepares guidelines for coastal management. Secondly, the federal Ministry of Environment, Forest & Climate Change (MoEFCC) ensures coordination between national level, state level and district level through its Integrated Coastal Zone Management Project Plan (ICZMP). While in case of the Netherlands, it is the Ministry of Transport, Public Works and Water Management that has Rijkswaterstaat (RWS), an executive body, responsible for the management of the major waters, such as the sea and the rivers. The Dutch ensure coastal protection coordination between various levels of their government (provincial, district, municipalities and regional water boards) based on their Water Act, 2009 (RWS 2009). For the sake of simplicity, this research did not make separate distinctions between the representatives of various bodies of governments, but instead government experts that have a role to play in coastal adaptation measures were contacted.
Private sector	Private businesses are not known to invest in large-scale restoration and sustainable management of natural assets for coastal protection due to a lack of appropriate incentives. This tendency, however, is set to alter as a result of improved information about the advantages the ocean and coastlines bring to people and growing acknowledgment among private economic players as environmental steward (Vegh et al. 2022). Thus, private sector can be seen involved in two ways – (1) private sector can actively invest when there is a specific risk to address, such as a risk to a business interest or asset located on the shore. (2) with public-private partnership flourishing across various regions, these are involved in construction and maintenance of SLR adaptation measures (Vegh et al. 2022). Such industry actors have first-hand knowledge and experience of actually doing the job and therefore, also know the pains associated with different adaptation measures. Furthermore, each of these industries specialises in one or more of the adaptation measures. For instance, Van Oord is known for its expertise in constructing dikes and beach nourishment in the Netherlands, Indonesia and the United Kingdom.

Stakeholder group	Role in SLR adaptation
International/Multilateral organisations	These organisations play a crucial role in responding to SLR adaptation measures by facilitating collaboration and coordination between nations and supporting the development and implementation of policies and programs at the international level. These organisations form a cooperative and sometimes legal binding framework across their member states by using a consensus-based approach. Such organisations support climate adaptation measures by providing knowledge (such as technical assistance and expertise), resources and funding. There are numerous initiatives, programmes and legal frameworks developed by the likes of UN, OECD, EU and IPCC. The Integrated Coastal Zone Management (ICZM), developed by the UN and adopted by various other governments and international organisations, is an example of such a framework (see Forrest 2006). With a need to have global consensus in standardisation, various representatives of international organisations were contacted to be on the panel.
Non Governmental Organisations (NGOs)	NGOs provide a community-based perspective and represent the interests of the nature (White et al. 2022). Thus, they stand for the under-represented sections of the society that face the majority of impacts of SLR. NGOs perform multi-fold roles in the process of coastal planning and management that include (1) mobilising communities, (2) information gathering and dissemination, (3) communication brokering i.e. facilitating communication between the government and the affected communities, (4) capacity building and education, and (5) providing technical assistance (Matindiı 1998; White et al. 2022). Take for instance, Care International, an NGO whose climate justice work focuses on community-based adaptation. Their coastal community adaptation project aims to build the resilience of coastal communities in Africa to climate change impacts through the activities discussed before (Care International 2015). Thus, to represent the interests of civil society and nature, the members from different NGOs were approached.
Research Community	This stakeholder group comprises individuals who come from academic and research institutions that have a specific research focus on SLR adaptation practices. It is also the case that the above mentioned stakeholder groups rely on the findings and recommendations of the research community to develop their plans for SLR adaptation. Consequently, it is necessary to involve researchers in the panel as their opinions are known to be backed by scientific evidence and, more importantly, they identify gaps in the plans of other stakeholders (Hayes et al. 2018).

Thus, we have identified five different stakeholder groups that are involved in the field of SLR adaptation. In line with requirements of the Delphi method and standardisation processes, the individuals who represent any of these stakeholder groups were deemed suitable to be elected in the Delphi committee.

3.3.2. Expert sampling strategy

Based on stakeholder identification and desk research, distinct categories of experts were delineated. Two sampling strategies were employed: the first involved soliciting expert participation for the panel, while the second centered on accruing information regarding expertise levels and organizational affiliations. Initially, experts were contacted through identification of stakeholder representatives via email addresses available on pertinent websites. These websites were ascertained using search terms related to stakeholder categories (e.g., ”NGO” for Non-governmental Organisations) combined with thematic keywords such as ”coastal adaptation” or ”coastal management.” This method facilitated identification of online sources representing each stakeholder category. Additionally, the literature review yielded contact information for individual researchers and research groups engaged in studies related to SLR

adaptation. Consequently, a total of 109 email addresses were obtained from websites, research papers, and affiliations associated with coastal adaptation experts and organisations.

Furthermore, LinkedIn platform was employed in dual capacities. Initially, efforts were directed towards locating and initiating connection requests with global experts in the realm of coastal adaptation. The search parameters encompassed terms such as "coastal adaptation," "coastal engineer," and "coastal management engineering." Connection requests were accompanied by concise 300-character messages, soliciting their engagement in the project. Upon acceptance of the connection request, a more comprehensive project overview was communicated through the platform's chat feature. Additionally, a separate action was taken whereby a LinkedIn post, incorporating a hyperlink to the online survey, was disseminated on the platform. To enhance the visibility of this post, members of the thesis committee were tagged, thereby broadening its potential audience. The email and LinkedIn invites shared for recruiting participants in the study are presented in the Appendix B.

3.4. Delphi rounds (May-June 2023)

Two rounds of Delphi studies were conducted in order to (1) identify SLR adaptation measures that could be globally standardised based on the consensus among the panellists (SQ2) and (2) understand why these SLR adaptation measures could be standardised? (SQ3).

3.4.1. Survey administration

The time duration for conducting each of the rounds was planned to be of 10 days, which is also minimum recommended duration in Delphi studies (Hsu et al. 2007; Beiderbeck et al. 2021). However, on request of certain panellists, the duration for collecting responses for round 1 was increased to 14 days. Along with giving sufficient time window for the expert pool to fill the survey, both the surveys were designed in a manner that they do not lead to participant fatigue. For this purpose, minimising the number of questions and the resultant time requirement to complete the survey was specifically discussed and implemented as a part of the survey review with the thesis committee. Therefore, only a set of 2 questions were asked in both the rounds that required greater expert efforts. As a result, both the rounds received above 20 responses, which is higher than the recommended 15 responses for a Delphi study (Hasson et al. 2000; Beiderbeck et al. 2021). Table 3.3 gives an overview of the time-period and responses for each of the round. The full list of questions and the options used in both the rounds of the study is provided in Appendix C. For clarity, we refer to clusters of responses by noting the question to which they responded, e.g., R1-Q3 would stand for responses given in round 1 of the Delphi study to question 3.

Table 3.3.: Survey delivery dates and responses

	Survey open	Survey close	Usable responses
Round 1	15.05.2023	29.05.2023	23
Round 2	19.06.2023	30.06.2023	22

As mentioned earlier, the surveys were distributed either as an email link or as an anonymous link on LinkedIn. The response rates for the email requests were calculated and are presented in Table 3.4. However, the response rates for the anonymous link could not be accurately calculated due to its wider reach and the inability to account for all the responses received in relation to the access to the anonymous link.

Table 3.4.: Email response rates for Delphi rounds

	Emails sent	Email response rate (Surveys finished)	Anonymous link responses
Round 1	98	15% (13)	10
Round 2	109	17% (18)	4

3.4.2. Delphi round 1 questionnaire

Round 1 (R1) asked respondents to brainstorm on the SLR adaptations measures that could be standardised. For this, the questionnaire was designed in two parts. Part 1 contained questions pertaining to the contact information, organisational affiliations and experience levels of the experts. Thus, part 1 helped in maintaining a contact list and understanding the composition of the Delphi panel. Furthermore, part 2 involved two questions:

1. **(R1-Q3)** Which of the following specific adaptation measures do you think could be globally standardised? Select all that apply.
2. **(R1-Q4)** Why these SLR adaptation measures could be standardised?

R1-Q3 was a multiple choice question (MCQ) with experts allowed to choose more than one option. The options contained (i) 28 SLR adaptation measures (identified as a part of the literature review, see Table 2.1), (ii) 3 open options to fill-up (in case the experts knew of any additional adaptation measure) and the last option was (iii) "None of the measures could be standardised". So as to avoid a biased inputs towards any of the adaptation measures, all 28 adaptation measures were subjected to choice randomisation, which was a readily available feature of the online survey tool used in the study. Thus, the adaptation measures appeared in a random sequence to every respondent.

R1-Q4 was an open-ended question. The respondents had to answer only for their choices in the previous question. Herein, respondents had to explain their rationale behind their choices made in the previous question.

The responses were analysed after closing the survey. The first question was analysed based on the counts for each of the choices of the participants. Whereas for the second question, qualitative data was subjected to a text analysis wherein the themes for each of the response were identified and grouped. The results were synthesised into a 3-page summary and a link to this summary was shared with respondents as a part of the invitation to round 2

3.4.3. Delphi round 2 questionnaire

Along with the summary, Round 2 (R2) was shared with a newer questionnaire to the existing R1 panellists and the same group of experts that were contacted in R1. Like R1, R2 questionnaire was also divided into two parts. The first part contained questions pertaining to the contact information, organisational affiliations and experience levels of the experts. However, only new respondents were asked about their organisational affiliations and experience levels.

The second part was designed to identify the consensus levels of the panellists for adaptation measures to be globally standardised. Following two questions were asked in R2:

1. **(R2-Q3)** Rate the following sea level rise adaptation measures for their suitability to be globally standardised. Use the following scale:
   1 - Strongly Disagree, 2 - Disagree, 3 - Neutral, 4 - Agree, 5 - Strongly Agree
2. **(R2-Q4)** Before we conclude, we would like to invite you to share any additional comments or feedback you may have. Please feel free to express any thoughts, concerns, suggestions, or ideas that you believe are relevant to sea level rise adaptation standardisation.

Each of the adaptation measures was opted at least once by the panellists to be standardised. Therefore, R2-Q3 contained all the SLR adaptation measures that were presented in R1 with a 5-point Likert scale options. Lastly, R2-Q4 was an open-ended question to collect any additional comments that the experts may have about the topic.

3.4.4. Delphi panel composition

In total, 31 experts from across 12 countries participated in both the Delphi rounds. As presented in Table 3.3, round 1 and round 2 had 23 and 22 responses respectively. However, only 14 panellists participated in both the rounds. Thus, round 2 had 8 (36%) new panellists. Figure 3.2 shows experience levels of experts and break-up of organisational affiliations of the panel.

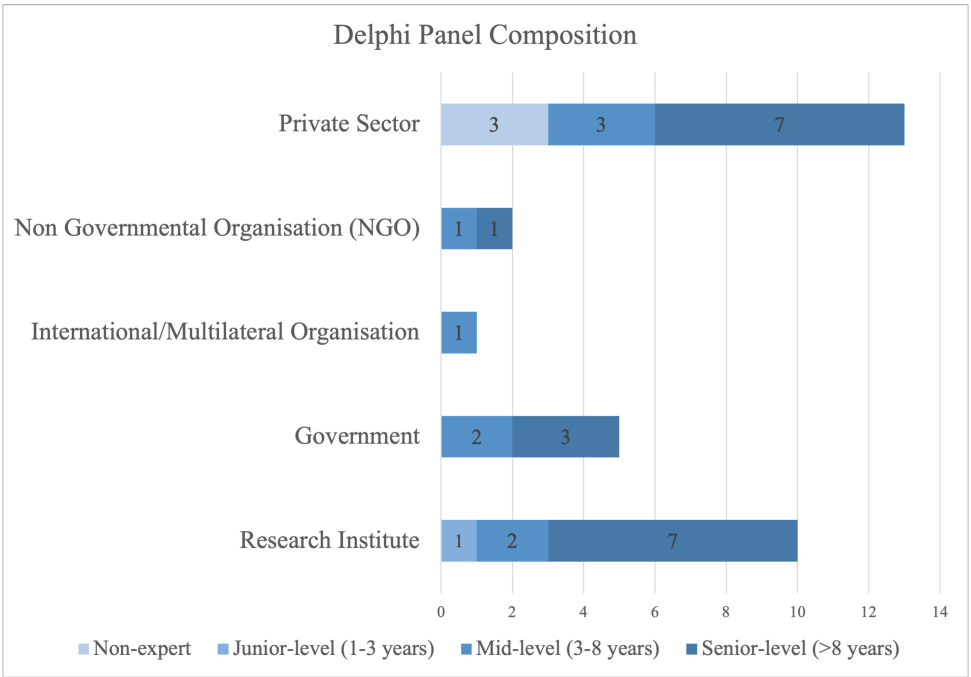


Figure 3.2.: Delphi panel composition

3.4.5. Defining consensus levels

There are two aspects to understanding how consensus level was set with respect to this study. Firstly, defining consensus itself; and secondly, a comparison between consensus in standardisation processes and Delphi study. Herein, the consensus levels that are required to identify SLR adaptation measures that could be globally standardised is defined.

Traditional consensus in group settings means full and unanimous agreement in a group, but such consensus is nearly impossible in real-world settings (Kacprzyk et al. 1988). Thus, consensus typically refers to reach consent rather than the agreement of all group participants (Herrera-Viedma et al. 2014). This type of consensus, as in this case, is usually defined as a soft consensus (Chao et al. 2022). The same approach to consensus is used by the standard developing committees. Next, reaching consensus in standardisation and the Delphi method can be compared based on (1) its definition, (2) process of reaching consensus and (3) set consensus levels as shown the Table 3.5. Since the study is aiming to explore consensus in developing global SLR adaptation standards, the comparison of consensus in Delphi study is done with that of ISO.

Table 3.5.: Comparison: Consensus in standardisation vs Delphi method

	Standardisation	Delphi Method
Definition	Consensus is set as goal of any technical committee. ISO defines consensus as, "general agreement where there is no sustained opposition to substantial issues by any important part of the concerned interests, in a process that seeks to take into account the views of all parties concerned" (see subclause 2.5.6 in the ISO/IEC Directives, Part 1).	Consensus is not necessarily the central objective or a measure of success of such studies (Gordon et al. 2006). Unlike standardisation, there is no direct contact between the expert panellists and the consensus considered to be reached if the panel exceeds a set threshold of agreement levels.

	Standardisation	Delphi Method
Process of reaching consensus	Consists of multiple consensus building phases. However, the final adoption takes place based on votes in the form of "Yes" or "No" by the technical committee for given standard. If approval criteria are not met, the draft standard is referred back to the originating committee for reconsideration in light of the technical reasons submitted in support of the negative votes received (see subclause 2.7.3 in the ISO/IEC Directives, Part 1).	The process runs in rounds and tends to move the expert panel's responses toward consensus. Usually, the agreement levels amongst the expert panellists is determined using a Likert-scale responses (see (Beiderbeck et al. 2021; Naughton et al. 2017). It also produces a set of reasons behind the responses (Gordon et al. 2006).
Consensus levels	If a two-thirds majority of the technical committee is in favour and not more than one-quarter of the total number of votes cast are negative the consensus levels are considered to be reached. Abstentions are excluded when the votes are counted, as well as negative votes not accompanied by technical reasons (see subclause 2.7.3 in the ISO/IEC Directives, Part 1).	There is no universally accepted levels because the level used is determined by sample size, research goal, and resources (Hasson et al. 2000; Hsu et al. 2007). Agreement levels anywhere between 50-80% among the expert panel are set to reach consensus (see Naughton et al. 2017; Taze et al. 2022).

Due to uncertainty around the number of participants who join and continue to participate in the subsequent rounds of the study, the consensus level (based on agreement levels) was set only after the end of the final round (R2). As presented in Section 3.4.4, the Delphi panel experienced significant participant attrition (36%). Hence, in order to accommodate for such a decline in the number of participants, the consensus level set for the study is 50% (i.e. by simple majority). This is calculated based on the agreement levels achieved for the responses to Likert-scaled based question R2-Q4 and is explained in detail in the Results section.

4. Results

This section contains results of part two of both the rounds of the Delphi study. The study generated a large amount of data over the course of two stages, not all of which can be presented here. Instead, the findings are organised around the questions as explained in the methodology section. The results are presented in a sequential manner as they build on each other. Thus, results of part two of round 1 and round 2 are presented from the first to last question as asked in the online survey.

4.1. Measures that could be standardised (R1-Q3)

In R1-Q3, 28 adaptation measures were given as options to indicate which of these could be standardised. Five additional measures were recommended by the experts for standardisation – these include mussel beds, sea grass, sand motor, infrastructure relocation and reefs. Figure 4.1 shows the count of the number of times each of these measures were chosen for standardisation. 19 out of 23 (83%) selected at least one SLR adaptation measure that could be standardised. While 4 (17%) indicated that *'None of the measures could be standardised'*.

4.2. Reasons for and against standardisation (R1-Q4)

R1-Q4, *"Why these SLR adaptation measures could be standardised?"* did not receive responses by all the panellists. 83% (19 out of 23) of the panellists responded to explain their rationale (these also include partially filled responses) for their choices made in R1-Q3. The results for this question are divided into two categories: (1) for standardisation and (2) against standardisation. Thus, based on the textual responses, the answers have been generalised for both aforementioned categories.

4.2.1. For standardisation

Following three major themes are identified for panellists' choice of opting an adaptation measures for standardisation:

1. Technical measure:

   Engineering-based measures that have fixed technical or design considerations. For eco-system based adaptation measures, experts have indicated that there are design/technical considerations involved in implementation of these. Thus, these measures have also been considered suitable to be standardised as a technical measure.

2. Pre-existing standard or methodology:

   Already existing standard or methodology for an adaptation measure that could be revised or newly drafted for SLR adaptation purpose.

3. Global data stream:

   Availability of a global data sharing facility for an adaptation measures and a possibility of global data standard such as for sharing, collection and interoperability.

Table 4.1 shows the measures that fall under each of the above three themes as opted by the panellists. A large portion of experts have indicated that adaptation measures could be standardised at a higher level and there is still a need to use location-specific information to implement adaptation measures. Within the responses in the category *for standardisation*, the panellists expressed a higher need to use location-specific considerations for certain adaptation measures (highlighted in grey) despite suggesting that these measures could be standardised. The location-specific consideration (such as geographic

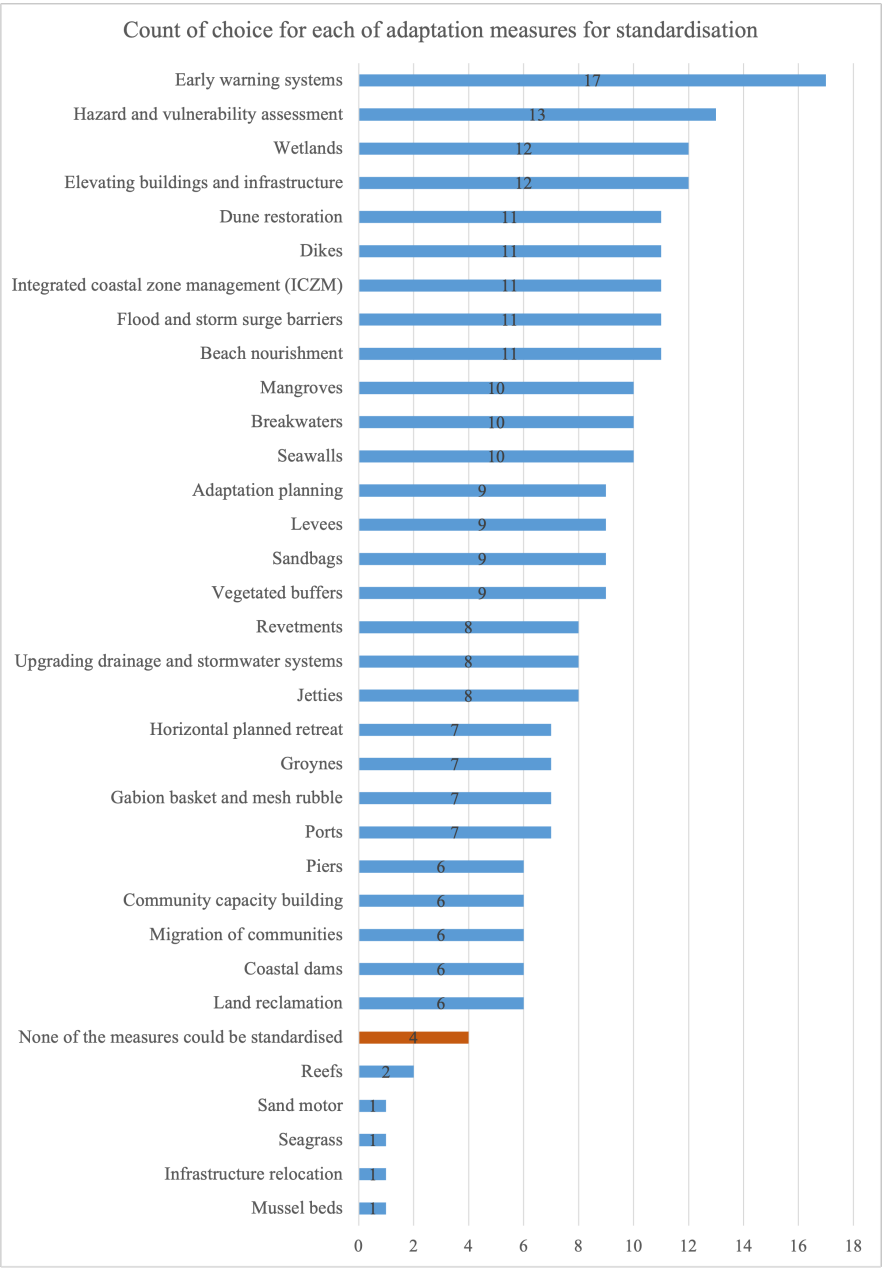


Figure 4.1.: Count of the expert's preference for standardisation of an adaptation measure

conditions, political uncertainty or variations legal frameworks) for each of the such measures differed. However, all the responses did not indicate these exact considerations. Therefore, no conclusive results can be drawn with respect to this aspect of the answers from the panel.

Table 4.1.: Reasons indicating the suitability of a particular adaptation measure for standardisation

Adaptation measure	Technical measure	Pre-existing standard or methodology	Global data stream
Early warning systems	✓	✓	✓
Hazard and vulnerability assessment	✓	✓	✓
Elevating buildings and infrastructure	✓	✓	
Wetlands*	✓		
Beach nourishment*	✓		
Flood and storm surge barriers	✓		
Integrated coastal zone management (ICZM)		✓	

Adaptation measure	Technical measure	Pre-existing standard or methodology	Global data stream
Dikes	✓		
Dune restoration*	✓		
Seawalls	✓		
Breakwaters	✓		
Mangroves*	✓		
Vegetated buffers*	✓		
Sandbags	✓		
Levees	✓		
Adaptation planning		✓	
Jetties	✓		
Upgrading drainage and stormwater systems	✓		
Revetments	✓		
Ports	✓	✓	
Gabion basket and mesh rubble	✓		
Groynes	✓		
Horizontal planned retreat			
Land reclamation	✓		
Coastal dams	✓		
Migration of communities			
Community capacity building			
Piers	✓		
Reefs*			
Mussel beds			
Infrastructure relocation			
Seagrass*			
Sand motor			

(: eco-system based adaptation measures)*

Measures requiring higher location-specific consideration than others

4.2.2. Against standardisation

Lastly, as mentioned before, 4 experts indicated that *'None of the measures could be standardised.'* The general reasons for such a choice by the expert panellists are:

1. Location-specific design requirements for each of the adaptation measures.
2. Variations in regional institutional and legal frameworks.
3. Political uncertainty and cultural differences at various locations.

4.3. Consensus levels for SLR adaptation measures to be globally standardised (R2-Q3)

The experts that opted *for standardisation* in R1 and R2 were only subjected to this question. The count of choices from the experts for each of the adaptation measure on a 5-point Likert scale (from Strongly Disagree to Strongly Agree) and the percentage agreement levels (% A) of the panellists are shown in the table 4.2. The group of experts that were *against standardisation* were added to the Disagree count. Thus, overall agreement levels for each of the adaptation measure were calculated based on the count of the experts who chose *Agree or Strongly Agree* as percentage of the total number of panellists in R2

(i.e. n=22). Those adaptation measures that achieve percentage agreement levels greater than or equal to 50% ($\%A \geq 50\%$) are deemed to have reached consensus.

Table 4.2.: % agreement for all adaptation measures that could be globally standardised

Adaptation measure	SD	D	N	A	SA	% A
Early warning systems	0	7	2	6	7	59
Seawalls	1	6	1	10	3	59
Levees	0	9	4	10	2	55
Sandbags	0	10	5	5	6	50
Dikes	0	7	2	10	1	50
Breakwaters (n=21)	0	9	4	6	4	48*
Flood and storm surge barriers	0	11	6	8	2	45
Dune restoration	0	10	5	6	4	45
Hazard and vulnerability assessment	0	9	4	6	4	45
Groynes (n=21)	0	8	3	8	1	43
Piers	0	12	7	6	3	41
Elevating buildings and infrastructure	0	12	7	6	3	41
Upgrading drainage and stormwater systems	0	11	6	5	4	41
Revetments	1	10	5	7	2	41
Ports	1	9	4	8	1	41
Beach nourishment	0	10	5	9	0	41
Jetties	1	10	5	6	2	36
Gabion basket and mesh rubble	0	10	5	6	2	36
Vegetated buffers	0	8	3	4	4	36
Wetlands	0	12	7	4	3	32
Adaptation planning	3	8	3	3	4	32
Coastal dams	2	9	4	5	2	32
Integrated coastal zone management (ICZM)	1	9	4	4	3	32
Community capacity building (n=21)	2	7	2	4	2	29
Mangroves	0	10	5	1	5	27
Infrastructure relocation	1	9	4	4	2	27
Reefs	0	13	8	3	2	23
Mussel beds	0	13	8	4	1	23
Migration of communities (n=21)	8	6	1	2	2	19
Sand motor (n=21)	2	9	4	4	0	19
Horizontal planned retreat	4	8	3	2	2	18
Land reclamation	4	8	3	3	1	18
Seagrass	0	11	6	3	1	18

(SD = strongly disagree, D = disagree, A = agree, SA = strongly agree, % A = % consensus)

Adaptation measures with % agreement $\geq$ 50%

** statement with % agreement close to the 50% cut-off – deemed as achieving consensus*

A total of six adaptation measures reached consensus within the expert panel to be developed into global standard – (1) Early Warning Systems (EWS), (2) Seawalls, (3) Levees, (4) Sandbags, (5) Dikes and (6) Breakwaters. These adaptation measures are highlighted in green in the Table 4.2. With consensus achieved, the Delphi study was concluded at the end of the second round and no further rounds were conducted. The following section covers the discussion on the overall research that also includes discussion on findings for both the rounds of the Delphi study.

5. Discussion

Being one of the first of its kinds study in the field of Sea Level Rise (SLR) adaptation standards, the research aimed at achieving two main objectives: (1) explore consensus on SLR adaptation measures that could be globally standardised and (2) demonstrate Delphi method as a way a cost-effective and time-saving method to develop standards. The study used a combination of desk-research and Delphi method to identify the SLR adaptation prospects so as to build a repository for global standardisation and gather expert opinions and consensus for measures that could be globally standardised. In this section, the overall results of the study based on the set sub-questions (SQs) including some of the unintended results, the theoretical implications of the study, the limitations of the study and scope for future research are discussed.

5.1. What are the available adaptation measures against SLR?

The literature review presents available adaptation measures against SLR (Section 2.1). The synthesis of adaptation measures draws upon the studies conducted by IPCC (1990), Dedekorkut-Howes et al. (2020), and Oppenheimer et al. (2019) serving as foundational references for the present analysis. However, the synthesis is exceptional in the sense that none of the previous studies offer a comprehensive summary of these adaptation measures in a single source. The same identified measures were posed as options to the experts in the Delphi study questionnaires. Furthermore, to add the initial review, the list of adaptation measures was further expanded based on the inputs in Round 1 of the study. Thus, the study was able to incorporate certain niche adaptation measures that were less-known in the literature

5.2. SLR adaptation measures that could (not) be standardised and reasons for standardisation

At the end of Round 2 of the study, six adaptation measures reached a consensus ($\%Agreement \geq 50\%$) within the expert panel, indicating their suitability for global standardisation (standardisable). On the other hand, there were five measures that received the highest percentage of disagreement ($\%D \geq 60\%$) and were deemed as could not be standardised (non-standardisable) by the panel. These findings are summarized in Table 5.1. The implications and interpretation of these results will be discussed in the following sub-sections.

Table 5.1.: Measures that could and could not be standardised

Standardisable		**Non-standardisable**	
Adaptation measure	% A	Adaptation measure	% D
Early warning systems	59	Migration of communities	76
Seawalls	59	Horizontal planned retreat	68
Levees	55	Land reclamation	68
Sandbags	50	Community capacity building	62
Dikes	50	Sand motor	62
Breakwaters	48*		

(% A = % agreement, % D = % disagreement)

** statement with % agreement close to the 50% cut-off – deemed as achieving consensus*

5.3. Reasons for and against standardisation

The reasons *for and against standardisation* were obtained in Round 1 and are categorised as shown in Table 5.2. These reasons are divided into three main themes. The reasons were found to be straightforward and provided meaningful insights, making additional improvements unnecessary as they were not the primary focus of the research. Therefore, the same question was not repeated in the subsequent round to prevent participant fatigue.

Table 5.2.: Reasons for and against standardisation of adaptation measures

For Standardisation	Against Standardisation
•Technical/Engineering-based measure	•Location-specific design considerations
•Pre-existing methodology or standard	•Variation in regional institutional and legal frameworks
•Possibility of global data stream	•Political uncertainty and cultural differences

When it comes to understanding the reasons for standardisation, another significant aspect of the study needs to be understood. This being a broader research on exploring consensus amongst a vast array of adaptation measures, the expert panel did not specifically choose to give detailed response to each adaptation measure, rather certain general and easy to grasp reasons were shared. Hence, the analysis reveals only three broad and intuitive themes.

5.3.1. Measures reaching consensus and a meta-criteria

The six adaptation measures that reached consensus are the measures that could be standardised (see Table 5.1). The reasons for such a choice by the panellists is given by the three themes under *for standardisation* category and specifies that a measures need to: (1 be) a technical measure, (2) have pre-existing standard or methodology that could be revised or newly drafted for SLR adaptation purpose and (3) have a possibility of a global data stream. These three collectively give us a **meta-criteria** to identify if a SLR adaptation measure could be standardised. The term meta-criteria signifies a criteria of criteria and is suitable since the panellists have shared the general reasons to yield the broad themes to develop standards.

Thus, the suitability of the adaptation measures reaching consensus to be globally standardised can be evaluated based on the set meta-criteria – firstly, all these measures are technical measures. Apart from early warning systems (EWS), the rest of five adaptation measures are hard-engineering based measures (Dedekorkut-Howes et al. 2020). Secondly, the panellists did not refer to any specific standards or methodology for each of the adaptation measure. Identifying the pre-existing standard or methodology for each adaptation measure would be out of the scope of this research. However, in the course of developing the research, some of the standards and methodologies such as standard operating procedures for EWS (UNDP 2019), engineering manuals for seawalls, levees, breakwaters and sandbags (USACE n.d.) and dikes standard (Jonkman et al. 2018; PBC 2021) were identified. Lastly, amongst the measures reaching consensus, the experts have identified that scope for having a global data stream only exists with EWS. For other adaptation measures the feasibility does not exist. Thus, we see all of the adaptation measures satisfy at least two out of the three requirements of the meta-criteria with EWS satisfying all of these three.

5.3.2. Measure deemed non-standardisable and relevance of standardisation

Among the five adaptation measures that the expert panel deemed as non-standardisable, four of them – migration of communities, horizontal planned retreat, community capacity building, and land reclamation – are recognized as reactive approaches in the literature (Dedekorkut-Howes et al. 2020; Jamero et al. 2018). These reactive measures also align with all three themes identified as arguments *against standardisation* and are known to be the least preferred options for tackling SLR. This explains the panel's disagreement in developing standards for these measures.

On the other hand, the sand motor is a relatively new and less-known measure, with its only current implementation observed in the Netherlands (Stive et al. 2013). This lack of familiarity and limited implementation could be the reason behind the disagreement among the panel members regarding its inclusion as a standardised choice.

Indeed, it may appear counter-intuitive to examine the relevance of standardisation concerning measures that were considered unsuitable for standardisation. However, it is essential to recognise that there is a distinction between a measure not being preferred for implementation and a measure not being suitable for development into a standard. These reactive measures may need to be implemented in situations where it is already or will soon be too late to implement proactive adaptation measures (Pinto et al. 2018). As a result, there seems to be a gap in understanding about the relevance of standardisation within the expert panel. This highlights the need for further exploration and clarification to ensure a comprehensive evaluation of the potential benefits and limitations of standardisation in the context of adaptation measures.

The reasoning themes identified by the expert panelists *against standardisation* are valid and have been acknowledged in the literature review of this study. However, it is essential to note that developing standards could serve as a means to address these concerns, as explained in Section 2.2. Standards created by respected bodies, such as ISO or CEN, are optional and considered 'voluntary' in nature (Dora 2018). These standards act as guidelines and recommendations for the relevant activities. Thus, even in the worst-case scenario, the set of reactive measures mentioned earlier may still be implemented and would require such guidelines in the form of standards. Furthermore, the notable emphasis on location-specific considerations, a central theme in opposition to standardisation, does carry a key limitation, as underscored by Sharaan et al. (2022). This limitation pertains to the observable phenomenon wherein distinct coastal adaptation authorities, sharing similar coastal geomorphology and processes, adopt disparate risk management and adaptation measures. In this context, standards could potentially offer significant advantages by providing a unifying framework for these divergent approaches.

5.4. The application of Delphi method in developing standards

To evaluate the effectiveness of the Delphi method in establishing global adaptation standards, we compare outcomes from round 1 (R1) and round 2 (R2) while also considering the overall ease of conducting the study. This assessment includes ease of forming an expert panel, gathering and analysing data, and the time required for the study.

Round 1 vs Round 2

The study had two rounds, and each round yielded different adaptation measures for standardisation. In R1 and R2, the rank-ordered output for adaptation measures differed, except for one measure (EWS) (see Table 5.3). The difference can be explained by how the questionnaires were set up in both rounds, specifically R1-Q3 and R2-Q3. In R1-Q3, participants were presented with adaptation options in a random order to avoid biased responses. However, in R2-Q3, the options were presented in the order of most to least preferred adaptation measures, based on R1 results. This order can influence participants' choices in web-based surveys, with options presented earlier receiving more responses (Solomon et al. 1994; Bacso et al. 2014). Additionally, the summary of R1 results shared with participants during R2 helped guide them in choosing adaptation measures that were better suited for standardisation, even if their original perceptions differed (the implicit meta-criteria). Thus, despite the order manipulation of adaptation options in the questionnaires, the participants eventually reached a consensus on the adaptation measures that could be standardised.

Table 5.3.: Comparison of results of round 1 and round 2

Rank	Round 1 (R1)	Round 2 (R2)
1	Early warning systems	Early warning systems
2	Hazard and vulnerability assessment	Seawalls
3	Elevating buildings and infrastructure	Levees
4	Wetlands	Sandbags
5	Beach nourishment	Dikes

The Delphi method proved to be a cost-effective and efficient approach for achieving the study's objectives. In just 5 months, the method facilitated the formation of an expert committee, who provided responses to open-ended and multiple-choice questions, leading to a consensus on six adaptation measures to be standardised globally. This demonstrated significant progress in terms of the practical ease of using the Delphi method for standardisation.

Additionally, the method's approach of sharing summaries and results from the previous round with the participants allowed for diverse stakeholders within the Delphi committee to learn about each other's perspectives. As a result, the method not only facilitated standardisation decisions but also contributed to spreading awareness about SLR adaptation standardisation among the stakeholders. Apart from intended results, the increased and much-needed awareness amongst a representative group of stakeholders about the topic is an achievement of the study. However, the Delphi method did have certain limitations which will be covered alongside the overall limitations of the study.

5.5. Theoretical implications of the research

In terms of of theory, there are multiple fronts where the study contributes to. Firstly, the study builds a repository of SLR adaptation measures, building extensively upon seminal works of IPCC (1990), Dedekorkut-Howes et al. (2020), and Oppenheimer et al. (2019). While the existing literature is largely focused on enlisting these adaptation measure, herein a description of processes and the wider known definitions of the adaptation measures is provided. It is worth noting, however, that the compilation of adaptation measures would need to be expanded and revised based on advancement in technology and increasing consensus to follow uniform terminology for these.

Secondly, the study slots in to fill the gap in literature between SLR adaptation and standardisation as it provides relevance of standardisation to the major challenges to SLR adaptation identified in the literature. These challenges (see Table 2.3) associated with the implementation of SLR adaptations, which are largely interlinked, are widely known in literature and have also been substantiated by the expert panellists. Consequently, the study contributes to theory-building by outlining how the adoption of standards can effectively tackle these challenges, thereby presenting a robust rationale for the global adoption of international standards. At the same time, the study also highlights the considerations that the standards so developed need to take into account as there is cannot be one-size-fits-all solution. These considerations include the elements of intrinsic adaptability and flexibility to have a site-specific approach, requirements of regular coordination amongst global stakeholders to ensure accessibility to information and efficient communication and, the use of best-available scientific understanding. In essence, this study not only advocates for the integration of international standards but also delineates the essential factors that should inform the crafting of such standards, taking into account the nuanced intricacies inherent to SLR adaptation.

Furthermore, building on the aforementioned achievement, we see how standards could be developed using the Delphi method. This aspect of the study addresses the underlying challenge with the lengthy processes of standardisation. With standards development process and the Delphi method having their own set of similarities (Goluchowicz et al. 2011), provided a strong case to utilise the Delphi method to achieve the objectives of the research. However, it is the process of reaching consensus that requires higher consideration as it is only after reaching consensus within the technical committee a standard could be published (ISO 2020). Hence, this research develops a comprehensive comparison between consensus in standardisation and the Delphi method (see Table 3.5). The comparison reveals that the Delphi method offers greater flexibility with regards to setting consensus levels as it takes a wider connotation to term "consensus". This adaptive attribute partially addresses the inherent limitation arising from the absence of direct interaction within the Delphi panel. Thus, this theoretical exploration not only sheds light on the potential alignment between the Delphi method and standards development, but it also offers future research works a direction and necessary assumptions that need to be considered in employing Delphi method to develop standards.

Lastly, the study introduces a meta-criteria for discerning SLR adaptation measures suitable for global standardisation. The term "meta-criteria" denotes a criterion that evaluates other criteria, and it checks three key themes to ascertain if an adaptation measure: (1) constitutes a technical measure, (2) possesses an existing methodology or standard that can be adapted or newly formulated for SLR adaptation, and (3) involves a global data stream conducive to facilitating the sharing, collection, and compatibility of SLR-related data. Among the set of adaptation measures that reached consensus, only Early Warning

Systems (EWS) met all three requirements of the meta-criteria. As such, the application of this meta-criteria to all SLR adaptation measures permits the identification of barriers impeding the development of standards for these measures. Consequently, overcoming these barriers for specific adaptation measures renders them suitable candidates for standardisation. In essence, this meta-criteria framework not only aids in pinpointing the adaptation measures suitable for standardisation but also outlines the criteria for their selection, thereby streamlining the process of developing global standards.

5.6. Limitations and scope for future research

This research study, like any piece of research, has limitations. Firstly, with just two rounds conducted in the Delphi study, a compromise was to be made related the number of questions asked to the panellist and further increasing consensus levels in the study. Additional questions on the *neutral* choices and the extreme choices of *strong disagreement* for a certain adaptation measures could not be asked. With the modified approach of including new panel members in the study for the second round, it was neither possible to collect responses through open questions nor to give an opportunity to reconsider their opinions on choice of SLR adaptation measures for standardisation unlike the participants from round 1. Conducting another round might have also helped increasing the percentage agreement on certain adaptation measures that were observed with high responses as *neutral* in Round 2. Secondly, though the study received enough responses in both the rounds, it experienced attrition of panellists between R1 and R2. About 36% of the panellists were new to R2, meaning the consensus levels achieved could have been different from what originally achieved if all the participants remained the same. Thirdly, the multiplicity of the adaptation measures caused the problem of respondent fatigue and lack of expertise in each of the adaptation measure of the panellists. Thus, a limited response rate was observed while collecting open answers for each of the adaptation measure in Round 1. Lastly, building on the previous limitation, the Likert-style questions for Round 2 for each of the adaptation measures were difficult to answer for the respondents and equally for the analysis. As mentioned earlier, there were a significant number of neutral responses that lead to ambiguity. Such ambiguities could have been well-addressed have there been interactions between the panellists, which was not possible because of the characteristics of the Delphi study itself.

The research being the starting point to bridge the gap between SLR adaptation and standardisation, can pave the way for future research in this field. To begin with, the identified meta-criteria from the study needs to be tested for all the adaptation measures. Especially, identifying pre-existing standards and methodologies for each of the available adaptation measures could make it easier to evaluate the standardisation scope of these. It also becomes crucial to study what aspects of the adaptation measures (such as design, maintenance, performance) could be globally standardised. The location-specific considerations for every adaptation measure cannot be ignored and that leaves room to identify what a *higher-level standard* means in the context of SLR adaptation measures. Lastly, the standardisation of integrated adaptation measures, essentially, those that involve combination of eco-system based and hard-engineering based measures needs to be evaluated (Pettorelli et al. 2021).

6. Conclusion and recommendations

Sea Level Rise (SLR) is a global challenge that is arising out of the cascading effects of climate change. The study starts with highlighting the need to shift attention to adaptation-based responses to SLR owing to its inevitability and irreversibility. Several issues associated with SLR adaptation were identified, which could well be addressed using standardisation. Global SLR adaptation standards are yet to be developed and require consensus from various international stakeholder groups. Thus, the main objective of the study was to explore consensus to develop global adaptation standards in response to SLR. The current method of developing international standards is known to be expensive and time-consuming and given the accelerated SLR, makes it urgent to adopt cost-effective and time-saving methods. As a result, the study also aimed at demonstrating the Delphi method, which also relies on reaching consensus within expert groups, as an efficient method to develop global adaptation standards.

The study makes crucial contributions for the advancement in the field of SLR adaptation and standardisation. Firstly, it develops a unique repository of SLR adaptation measures that could be further expanded and revised. Secondly, it clarifies relevance the standardisation in relation to the challenges posed with SLR adaptation implementation. Lastly, it provides necessary considerations to improve understanding of consensus levels in developing standards vis-à-vis the Delphi method.

The six adaptation measures that achieved consensus to be developed into a global adaptation standard at the end of the study are: (1) Early warning systems, (2) Seawalls, (3) Levees, (4) Sandbags, (5) Dikes, and (6) Breakwaters. These measures were selected based on newly identified meta-criteria as part of the study. The meta-criteria consist of three conditions related to adaptation measures: (1) a technical measure, (2) measures with existing methodologies or standards that can be revised or newly drafted for SLR adaptation, and (3) the possibility of a global data stream for an adaptation measure to facilitate data sharing, collection, and interoperability. All the chosen measures fulfilled at least two out of the three conditions. While these six adaptation measures prioritise attainable goals that can be easily developed into standards, it is essential to acknowledge that their reliance on hard-engineering may not be sustainable in the long run, as demonstrated in a series of studies (Dedekorkut-Howes et al. 2020; Pettorelli et al. 2021). Therefore, there is a need to place greater emphasis on integrated adaptation measures that incorporate eco-system based approaches.

Finally, with there being considerable amount of complexity to identify the starting point to develop global SLR adaptation standards, the Delphi method proved to be successful in reaching consensus in a cost-effective and time-saving manner. However, there exist certain limitations arising owing to the modified approach of the Delphi study that led to new participants joining as well attrition of participants. One area where the Delphi method could be improved is enhancing the interaction between the panellists to address these limitations.

6.1. Societal and EPA relevance

I believe the societal and Engineering and Policy Analysis (EPA) relevance of the work are very much intertwined – as the master's program looks to address grand societal challenges by analysing and solving complex problems that involve many parties with conflicting interests. It is obvious that sea level rise is a grand challenge (Gibbs 2016), arising out of the cascading effects of climate change, that requires long-term planning involving a variety of stakeholders. Crucially, the impact of SLR is largely felt by the underprivileged sections of the society (Donner et al. 2014). The development of adaptation standards on an international scale stands at the crossroads of technical acumen, channeled through expert insights, and the imperative for social inclusivity, by affording equitable access (Dora 2018). Thus, standards, governed by consensus, balances the interests of the society without compromising efficacy of adaptation standards.

This study is a sincere attempt to be of support in the grand scheme of challenges and uncertainty that SLR brings to the globe. In doing so, the study tries to bring in practice the various roles and

analytical styles that a policy analyst needs to perform as given by Mayer et al. (2004). The study while employing the imparted research and analysis skills, democratises the use of standards by putting forth the option to develop global adaptation standards in response to SLR. An interesting outcome turns out of clarifying values and arguments within the global community of experts in relation to the voluntary nature of international standards. Manifestly, the study adeptly adheres to participatory, interactive, and argumentative analytical modalities across disparate phases of the research (Mayer et al. 2004).

6.2. Policy recommendations

The study has identified a set of six adaptation measures that could achieve global standardisation through consensus. However, to streamline the standardisation process for not only these measures but also for the entire array of adaptation measures, three actionable policy recommendations can be deduced from the research:

1. **Develop a consistent global language for SLR adaptation strategies and measures, including a classification of these measures.** This can be achieved through international *''fundamental standards"* involving terminology, conventions, signs, and symbols (CEN 2020). Collaborate internationally to build consensus. This research contributes to laying the groundwork for such a shared terminology (see Table 2.1).
2. **Raise awareness about the significance of standardisation in SLR adaptation among the worldwide community of stakeholders in this field**. Options include educational campaigns highlighting the benefits and features of standardisation, and participation in major global events like the UN Climate Change Conference, emphasising the importance of climate adaptation standards (Dora 2018). While multiple stakeholders can be involved, it is recommended that leading international standardisation bodies such as ISO and CEN take the lead. Such awareness efforts can help address any concerns that coastal adaptation experts may have regarding global standardisation.
3. **Establish a global platform for sharing appropriate SLR information usable across various adaptation measures.** Based on input from experts transformed into a meta-criteria, only Early Warning Systems (EWS) appear feasible for a global data stream. Even for one of the most basic SLR information such as SLR projections there does not exist a uniform approach (Box et al. 2022; Hirschfeld et al. 2023). With a global threat, there is a need for a global data standard. Following the approach suggested by Cozannet et al. (2017), developing standardised methods for translating relative sea level information into usable formats is essential, such as Coastal Communication Services (CCS), to inform a broad array of pertinent coastal management decisions, including adaptation.

In conclusion, the study has acknowledged the significance of standardisation in supporting the argument for developing global adaptation standards for sea level rise (SLR) adaptation. Nonetheless, it is important to recognise the validity of reasons presented against standardisation and the need for location-specific considerations for each adaptation measure. Thus, the development of standards that take these considerations into account can indeed offer the much-needed flexibility and adaptability to address unforeseen circumstances.

Bibliography

Adger, W Neil, Hallie Eakin, and Alexandra Winkels (2009). "Nested and teleconnected vulnerabilities to environmental change". In: *Frontiers in Ecology and the Environment* 7.3, pp. 150–157.

Alverson, Keith (Sept. 2012). "Vulnerability, impacts, and adaptation to sea level rise taking an ecosystem-based approach". In: *Oceanography* 25 (3), pp. 231–235. ISSN: 10428275. DOI: 10.5670/oceanog.2012.101.

Bacso, Petra, Diego Quintanilha, and Miranda Pereira (2014). *Web Design and Usability Issues: How people read Webpages*. URL: https://core.ac.uk/download/pdf/38112357.pdf.

Beavers, R.L., A.L. Babson, and C.A. Schupp (2016). *Coastal Adaptation Strategies Handbook - Climate Change (U.S. National Park Service)*. Tech. rep. NPS 999/134090. URL: https://www.nps.gov/subjects/climatechange/coastalhandbook.htm.

Beiderbeck, Daniel, Nicolas Frevel, Heiko A. von der Gracht, Sascha L. Schmidt, and Vera M. Schweitzer (Apr. 2021). "The impact of COVID-19 on the European football ecosystem – A Delphi-based scenario analysis". In: *Technological Forecasting and Social Change* 165. ISSN: 00401625. DOI: 10.1016/j.techfore.2021.120577.

Bowering, Ethan (2014). "Adapting to climate-induced sea level rise on the Gold Coast: lessons from the Netherlands". In: *Australian Planner* 51.4, pp. 340–348.

Box, Jason E et al. (2022). "Greenland ice sheet climate disequilibrium and committed sea-level rise". In: DOI: 10.1038/s41558-022-01441-2. URL: https://doi.org/10.1038/s41558-022-01441-2.

Breugel, Luuk van (2022). "Consensus in technology selection for Small Modular Reactors". Available at http://repository.tudelft.nl/.. Master thesis. Delft, NL: Delft University of Technology.

Brown, Sally, Katie Jenkins, et al. (2021). "Global costs of protecting against sea-level rise at 1.5 to 4.0 °C". In: DOI: 10.1007/s10584-021-03130-z. URL: https://doi.org/10.1007/s10584-021-03130-z.

Brown, Sally, Matthew P. Wadey, Robert J. Nicholls, Ali Shareef, Zammath Khaleel, Jochen Hinkel, Daniel Lincke, and Maurice V. McCabe (2020). "Land raising as a solution to sea-level rise: An analysis of coastal flooding on an artificial island in the Maldives". In: *Journal of Flood Risk Management* 13.S1, e12567. DOI: https://doi.org/10.1111/jfr3.12567. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/jfr3.12567. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jfr3.12567.

Care International (2015). *Adaptation Learning Programme for Africa*. URL: https://careclimatechange.org/wp-content/uploads/2016/03/ALP-2010-15-Report.pdf (visited on 05/02/2023).

CEN, European Committee for Standardization (2020). *Standards for Environment*. URL: https://www.cencenelec.eu/media/CEN-CENELEC/AreasOfWork/CEN-CENELEC_Topics/Environment%20and%20Sustainability/Quicklinks%20General/Documentation%20and%20Materials/brochureenvironnement_2020.pdf.

— (Mar. 2022). *Tailored guidance for standardization technical committees: How to include Adaption to Climate Change (ACC) in European infrastructure standards*. URL: https://boss.cen.eu/media/BOSS%20CEN/ref/climate_adpatation_in_standards_guidance.pdf.

Chao, Xiangrui, Yucheng Dong, Gang Kou, and Yi Peng (Sept. 2022). "How to determine the consensus threshold in group decision making: a method based on efficiency benchmark using benefit and cost insight". In: *Annals of Operations Research* 316 (1), pp. 143–177. ISSN: 15729338. DOI: 10.1007/s10479-020-03927-8.

Climate-ADAPT (2023a). *Restoration and management of coastal wetlands*. URL: https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/restoration-and-management-of-coastal-wetlands.

— (2023b). *Storm surge gates and flood barriers — English*. URL: https://climate-adapt.eea.europa.eu/en/metadata/adaptation-options/storm-surge-gates-flood-barriers.

Colgan, William et al. (2022). "Sea-level rise in Denmark: paleo context, recent projections and policy implications". In: *GEUS Bulletin* 49. ISSN: 25972154. DOI: 10.34194/GEUSB.V49.8315.

Cozannet, Gonéri Le, Robert J. Nicholls, Jochen Hinkel, William V. Sweet, Kathleen L. McInnes, Roderik S.W. Van de Wal, Aimée B.A. Slangen, Jason A. Lowe, and Kathleen D. White (Oct. 2017). "Sea level change and coastal climate services: The way forward". In: *Journal of Marine Science and Engineering* 5 (4). ISSN: 20771312. DOI: 10.3390/jmse5040049.

Dalkey, Norman and Olaf Helmer (1963). "An Experimental Application of the DELPHI Method to the Use of Experts". In: *Management Science* 9.3, pp. 458–467. DOI: 10.1287/mnsc.9.3.458. URL: https://ideas.repec.org/a/inm/ormnsc/v9y1963i3p458-467.html.

de Vries, H.J., Bert Nagtegaal, and Stijn Veenstra (2017). "Transatlantic Harmonisation of Standards and Conformity Assessment: A Business Perspective". English. In: *EURAS Proceedings 2017*. Ed. by Kai Jakobs and Knut Blind. Wissenschaftsverlag Mainz, T39–T58.

Dedekorkut-Howes, Ayşın, Elnaz Torabi, and Michael Howes (2020). "When the tide gets high: a review of adaptive responses to sea level rise and coastal flooding". In: *Journal of Environmental Planning and Management* 63.12, pp. 2102–2143. DOI: 10.1080/09640568.2019.1708709. eprint: https://doi.org/10.1080/09640568.2019.1708709. URL: https://doi.org/10.1080/09640568.2019.1708709.

Denamiel, Cléa, Xun Huan, and Ivica Vilibić (May 2021). "Conceptual Design of Extreme Sea-Level Early Warning Systems Based on Uncertainty Quantification and Engineering Optimization Methods". In: *Frontiers in Marine Science* 8. ISSN: 22967745. DOI: 10.3389/fmars.2021.650279.

Donner, Simon D. and Sophie Webber (Jan. 2014). "Obstacles to climate change adaptation decisions: A case study of sea-level rise and coastal protection measures in Kiribati". In: *Sustainability Science* 9 (3), pp. 331–345. ISSN: 18624057. DOI: 10.1007/S11625-014-0242-Z/TABLES/3. URL: https://link.springer.com/article/10.1007/s11625-014-0242-z.

Doorn, Neelke (June 2016). "Governance Experiments in Water Management: From Interests to Building Blocks". In: *Science and Engineering Ethics* 22 (3), pp. 755–774. ISSN: 14715546. DOI: 10.1007/s11948-015-9627-3.

Dora, John (2018). *Climate change: Standards, and their role in improving the climate resilience of infrastructure investments*. Tech. rep. URL: https://www.ebrd.com/documents/climate-finance/climate-change-standards-and-their-role-in-improving-the-climate-resilience-of-infrastructure-investments.pdf.

Farrell, Joseph and Timothy Simcoe (2012). *Choosing the rules for consensus standardization*, pp. 235–252.

Forrest, Craig (2006). *Integrated Coastal Zone Management: A Critical Overview*. DOI: 10.1007/BF03195105. URL: http://ioc.unesco.org/icam/default.htm#WHAT%5C%20IS%5C%20INTEGRATED%5C%20COASTAL%5C%.

Furman, Jeffrey, Michael Porter, and Scott Stern (Aug. 2002). "The Determinants of National Innovative Capacity". In: *Research Policy* 31, pp. 899–933. DOI: 10.1016/S0048-7333(01)00152-4.

Gibbs, Mark T. (2016). "Why is coastal retreat so hard to implement? Understanding the political risk of coastal adaptation pathways". In: *Ocean Coastal Management* 130, pp. 107–114. ISSN: 0964-5691. DOI: https://doi.org/10.1016/j.ocecoaman.2016.06.002. URL: https://www.sciencedirect.com/science/article/pii/S0964569116301119.

Gilman, Eric L., Joanna Ellison, Norman C. Duke, and Colin Field (2008). "Threats to mangroves from climate change and adaptation options: A review". In: *Aquatic Botany* 89.2. Mangrove Ecology – Applications in Forestry and Costal Zone Management, pp. 237–250. ISSN: 0304-3770. DOI: https://doi.org/10.1016/j.aquabot.2007.12.009. URL: https://www.sciencedirect.com/science/article/pii/S030437700800003X.

Goluchowicz, Kerstin and Knut Blind (Nov. 2011). "Identification of future fields of standardisation: An explorative application of the Delphi methodology". In: *Technological Forecasting and Social Change* 78 (9), pp. 1526–1541. ISSN: 00401625. DOI: 10.1016/j.techfore.2011.04.014.

Gordon, Theodore and Adam Pease (May 2006). "RT Delphi: An efficient, "round-less" almost real time Delphi method". In: *Technological Forecasting and Social Change* 73 (4), pp. 321–333. ISSN: 00401625. DOI: 10.1016/j.techfore.2005.09.005.

Hall, John A. et al. (Mar. 2019). "Rising Sea Levels: Helping Decision-Makers Confront the Inevitable". In: *Coastal Management* 47 (2), pp. 127–150. ISSN: 15210421. DOI: 10.1080/08920753.2019.1551012.

Harwitasari, D. and Jacko A. van Ast (Sept. 2011). "Climate change adaptation in practice: People's responses to tidal flooding in Semarang, Indonesia". In: *Journal of Flood Risk Management* 4 (3), pp. 216–233. ISSN: 1753318X. DOI: 10.1111/j.1753-318X.2011.01104.x.

Hasson, Felicity, Sinead Keeney, and Hugh McKenna (2000). "Research guidelines for the Delphi survey technique". In: *Journal of Advanced Nursing* 32 (4), pp. 1008–1015. ISSN: 03092402. DOI: 10.1046/j.1365-2648.2000.t01-1-01567.x.

Hayes, Adam L., Eliza C. Heery, Elizabeth Maroon, Anna K. McLaskey, and Christine C. Stawitz (2018). "The role of scientific expertise in local adaptation to projected sea level rise". In: *Environmental Science Policy* 87, pp. 55–63. ISSN: 1462-9011. DOI: https://doi.org/10.1016/j.envsci.2018.05.012. URL: https://www.sciencedirect.com/science/article/pii/S1462901117312261.

Herrera-Viedma, Enrique, Francisco Javier Cabrerizo, Janusz Kacprzyk, and Witold Pedrycz (2014). "A review of soft consensus models in a fuzzy environment". In: *Information Fusion* 17 (1), pp. 4–13. ISSN: 15662535. DOI: 10.1016/j.inffus.2013.04.002.

Hirschfeld, Daniella et al. (Apr. 2023). "Global survey shows planners use widely varying sea-level rise projections for coastal adaptation". In: *Communications Earth Environment* 4. DOI: 10.1038/s43247-023-00703-x.

Hoffmann, Matthew (Jan. 2011). *Climate Governance at the Crossroads: Experimenting with a Global Response after Kyoto*.

Houston, James (2013). "Sea Level Rise". In: *Coastal Hazards*. Ed. by Charles W. Finkl. Dordrecht: Springer Netherlands, pp. 245–266. ISBN: 978-94-007-5234-4. DOI: 10.1007/978-94-007-5234-4_10. URL: https://doi.org/10.1007/978-94-007-5234-4_10.

Hsu, Chia-Chien and Brian A Sandford (2007). "The Delphi Technique: Making Sense of Consensus". In: *Practical Assessment, Research, and Evaluation* 12, p. 10. DOI: 10.7275/pdz9-th90.

IPCC, Intergovernmental Panel on Climate Change (1990). *Strategies for adaptation to sea level rise*. Citeseer.

— (2018). "Global warming of 1.5 C". In: *An IPCC Special Report on the impacts of global warming of , Masson-Delmotte, Valérie and Zhai, Panmao and Pörtner, Hans-Otto and Roberts, Debra and Skea, Jim and Shukla, Priyadarshi R and Pirani, Anna and Moufouma-Okia, Wilfran and Péan, Clotilde and Pidcock, Roz and others* 1.5.

— (2022). "Climate change 2022: impacts, adaptation and vulnerability". In: *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]*

ISO, International Organisation for Standardisation (2020). *Developing standards*. URL: https://www.iso.org/developing-standards.html.

Jamero, Ma Laurice, Motoharu Onuki, Miguel Esteban, and Nicholson Tan (Dec. 2018). "Community-based adaptation in low-lying islands in the Philippines: challenges and lessons learned". In: *Regional Environmental Change* 18 (8), pp. 2249–2260. ISSN: 1436378X. DOI: 10.1007/S10113-018-1332-8.

Johnston, A., P. Slovinsky, and K. L. Yates (2014). "Assessing the vulnerability of coastal infrastructure to sea level rise using multi-criteria analysis in Scarborough, Maine (USA)". In: *Ocean and Coastal Management* 95, pp. 176–188. ISSN: 09645691. DOI: 10.1016/j.ocecoaman.2014.04.016.

Jonkman, Sebastiaan N, Hessel G Voortman, Jan Klerk, and Saskia Van Vuren (2018). "Structure and Infrastructure Engineering Maintenance, Management, Life-Cycle Design and Performance Developments in the management of flood defences and hydraulic infrastructure in the Netherlands". In: *Structure and InfraStructure engIneerIng* 14 (7), pp. 895–910. ISSN: 1744-8980. DOI: 10.1080/15732479.2018.1441317. URL: https://www.tandfonline.com/action/journalInformation?journalCode=nsie20.

Kacprzyk, Janusz and Mario Fedrizzi (1988). *Theory and Methodology A 'soft' measure of consensus in the setting of partial(fuzzy) preferences*, pp. 316–325.

Kumar, Prashant et al. (2020). "Towards an operationalisation of nature-based solutions for natural hazards". In: *Science of The Total Environment* 731, p. 138855. ISSN: 0048-9697. DOI: https://doi.org/10.1016/j.scitotenv.2020.138855. URL: https://www.sciencedirect.com/science/article/pii/S004896972032372X.

Lal, Padma Narsey et al. (2012). "National Systems for Managing the Risks from Climate Extremes and Disasters". In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. Ed. by Christopher B. Field, Vicente Barros, Thomas F. Stocker, and QinEditors Dahe. Cambridge University Press, pp. 339–392. DOI: 10.1017/CBO9781139177245.009.

Laurice Jamero, Ma, Motoharu Onuki, Miguel Esteban, Xyza Kristina Billones-Sensano, Nicholson Tan, Angelie Nellas, Hiroshi Takagi, Nguyen Danh Thao, and Ven Paolo Valenzuela (2017). "Small-island communities in the Philippines prefer local measures to relocation in response to sea-level rise". In: *Nature Climate Change* 7.8, pp. 581–586.

Lawrence, Judy, Frances Sullivan, Alison Lash, Gavin Ide, Chris Cameron, and Lisa McGlinchey (2015). "Adapting to changing climate risk by local government in New Zealand: institutional practice barriers and enablers". In: *Local Environment* 20.3, pp. 298–320. DOI: 10.1080/13549839.2013.839643.

Leal, K.B., L.E.S. Robaina, and A.S. De Lima (2022). "Coastal impacts of storm surges on a changing climate: a global bibliometric analysis". In: *Natural Hazards*. cited By 1. DOI: 10.1007/s11069-022-05432-6. URL: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85131797089&doi=10.1007%5C%2fs11069-022-05432-6&partnerID=40&md5=d7d6f13c1428b3c1621e21a4888b9e40.

Linares, Paola Bianca Cisneros (Apr. 2012). "Sea level rise impacts in coastal zones: Soft measures to cope with it". In: *Dalhousie Journal of Interdisciplinary Management* 8 (2). DOI: 10.5931/djim.v8i2.282.

Lindner, René, Daniel Lückerath, Josune Hernantes, Carmen Jaca, Vasileios Latinos, and Katherine Peinhardt (2021). "Bringing Research on City Resilience to Relevant Stakeholders—Combining Co-creation and Standardization in the ARCH project". In: *Proceedings of the 26th International Conference on Urban Planning, Regional Development and Information Society, Vienna, Austria*, pp. 7–10.

Lorie, Mark et al. (Jan. 2020). "Modeling coastal flood risk and adaptation response under future climate conditions". In: *Climate Risk Management* 29. ISSN: 22120963. DOI: 10.1016/J.CRM.2020.100233.

Marshall, Ariana and Marcia Allen Owens (2014). *The International Journal of Climate Change: Impacts and Responses Informing Rural Sea-Level Adaptatoin Strategies through Public Participation Evaluation Application of the Policy Window Theory*. DOI: https://doi.org/10.18848/1835-7156/CGP/v05i02/37205. URL: http://on-climate.com/.

Martin, Maxmillan, Yi hyun Kang, Motasim Billah, Tasneem Siddiqui, Richard Black, and Dominic Kniveton (2017). "Climate-influenced migration in Bangladesh: The need for a policy realignment". In: *Development Policy Review* 35.S2, O357–O379. DOI: https://doi.org/10.1111/dpr.12260. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/dpr.12260. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/dpr.12260.

Matindıı, Susan (1998). *The Role of Non Government Organizations in Coastal Planning and Management*. URL: https://aquadocs.org/handle/1834/8470.

Mayer, Igor S, C Els Van Daalen, and Pieter WG Bots (2004). "Perspectives on policy analyses: a framework for understanding and design". In: *International Journal of Technology, Policy and Management* 4.2, pp. 169–191.

McNamee, Kerry, Evan Wisheropp, Christopher Weinstein, Andrew Nugent, and Laurie Richmond (2014). "Scenario Planning for Building Coastal Resilience in the Face of Sea Level Rise: The Case of Jacobs Avenue, Eureka, CA". In: *Humboldt Journal of Social Relations* 36, pp. 145–173. ISSN: 01604341. URL: http://www.jstor.org/stable/humjsocrel.36.145 (visited on 09/25/2022).

Melville-Rea, Hannah et al. (July 2021). "A Roadmap for Policy-Relevant Sea-Level Rise Research in the United Arab Emirates". In: *Frontiers in Marine Science* 8. ISSN: 22967745. DOI: 10.3389/fmars.2021.670089.

Musa, Zahrah N., Ioana Popescu, and Arthur Mynett (2016). "Assessing the sustainability of local resilience practices against sea level rise impacts on the lower Niger delta". In: *Ocean Coastal Management* 130, pp. 221–228. ISSN: 0964-5691. DOI: https://doi.org/10.1016/j.ocecoaman.2016.06.016. URL: https://www.sciencedirect.com/science/article/pii/S0964569116301259.

Myszewski, Margaret and Merryl Alber (2014). *Vegetated Buffers in the Coastal Zone Prepared for GA DNR-Coastal Resources Division*. URL: https://www.gcrc.uga.edu/wp-content/uploads/2019/09/Final-Vegetated-Buffers-in-the-Coastal-Zone.pdf.

Naughton, Bernard, Lindsey Roberts, Sue Dopson, David Brindley, and Stephen Chapman (2017). "Medicine authentication technology as a counterfeit medicine-detection tool: a Delphi method study to establish expert opinion on manual medicine authentication technology in secondary care". In: DOI: 10.1136/bmjopen-2016. URL: http://dx.doi.org/10.1136/bmjopen-2016-013838.

Nicholls, R and F M J Hoozemansb (1996). *The Mediterranean: vulnerability to coastal implications of' climate change*, pp. 10–15.

Nicholls, Robert J. (2011). "Planning for the Impacts of Sea Level Rise". In: *Oceanography* issue$_v$*olume*. URL: https://doi.org/10.5670/oceanog.2011.34.

Nordstrom, Karl F. (2008). *Beach and Dune Restoration*. Cambridge University Press. DOI: 10.1017/CBO9780511535925.

OECD (2019). *Responding to Rising Seas*, p. 168. DOI: https://doi.org/https://doi.org/10.1787/9789264312487-en. URL: https://www.oecd-ilibrary.org/content/publication/9789264312487-en.

Oppenheimer, M. et al. (2019). "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities". In: ed. by H.-O. Pörtner et al., pp. 321–445. DOI: 10.1017/9781009157964.006. URL: https://www.ipcc.ch/srocc/chapter/chapter-4-sea-level-rise-and-implications-for-low-lying-islands-coasts-and-communities/.

PBC (May 2021). *Dike Design and Construction Guidelines - Province of British Columbia (PBC)*. URL: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/integrated-flood-hazard-management/dike-management/design-construction.

Pettorelli, Nathalie, Nicholas A.J. Graham, Nathalie Seddon, Mercedes Maria da Cunha Bustamante, Matthew J. Lowton, William J. Sutherland, Heather J. Koldewey, Honor C. Prentice, and Jos Barlow (Nov. 2021). "Time to integrate global climate change and biodiversity science-policy agendas". In: *Journal of Applied Ecology* 58 (11), pp. 2384–2393. ISSN: 13652664. DOI: 10.1111/1365-2664.13985.

Pinto, Pedro J., G. Mathias Kondolf, and Pun Lok Raymond Wong (Dec. 2018). "Adapting to sea level rise: Emerging governance issues in the San Francisco Bay Region". In: *Environmental Science and Policy* 90, pp. 28–37. ISSN: 18736416. DOI: 10.1016/j.envsci.2018.09.015.

RWS, Rijkswaterstaat (2009). "Water Act". In: *Ministry of Transport, Public Works and Water Management, the Netherlands*. URL: https://www.helpdeskwater.nl/secundaire-navigatie/english/@176675/dutch-water-act/.

Sharaan, Mahmoud, Moheb Iskander, and Keiko Udo (Mar. 2022). "Coastal adaptation to Sea Level Rise: An overview of Egypt's efforts". In: *Ocean and Coastal Management* 218. ISSN: 09645691. DOI: 10.1016/j.ocecoaman.2021.106024.

Solomon, Michael R and Consumer Behavior (1994). "Buying, having and being". In: *London: Prenticle Hall*.

Sourani, Amr and Mu Sohail (Aug. 2014). "The Delphi Method: Review and Use in Construction Management Research". In: *International Journal of Construction Education and Research* 11, pp. 54–76. DOI: 10.1080/15578771.2014.917132.

Stephens, Sonia H., Denise E. DeLorme, and Scott C. Hagen (Sept. 2020). "Coastal Stakeholders' Perceptions of Sea Level Rise Adaptation Planning in the Northern Gulf of Mexico". In: *Environmental Management* 66 (3), pp. 407–418. ISSN: 14321009. DOI: 10.1007/s00267-020-01315-3.

Stive, Marcel et al. (June 2013). "The sand engine: A solution for vulnerable deltas in the 21st century?" In.

Taze, Dilek, Collette Hartley, Ann W Morgan, Aruna Chakrabarty, Sarah L Mackie, and Kathryn J Griffin (2022). "Developing consensus in Histopathology: the role of the Delphi method". In: *Histopathology* 81.2, pp. 159–167. DOI: https://doi.org/10.1111/his.14650. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/his.14650. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/his.14650.

Tiggeloven, Timothy et al. (Apr. 2020). "Global-scale benefit-cost analysis of coastal flood adaptation to different flood risk drivers using structural measures". In: *Natural Hazards and Earth System Sciences* 20 (4), pp. 1025–1044. ISSN: 16849981. DOI: 10.5194/nhess-20-1025-2020.

Titus, James G., Chin Y. Kuo, Michael J. Gibbs, Tom B. LaRoche, M. Keith Webb, and Jesse O. Waddell (1987). "Greenhouse Effect, Sea Level Rise, and Coastal Drainage Systems". In: *Journal of Water Resources Planning and Management* 113.2, pp. 216–227. DOI: 10.1061/(ASCE)0733-9496(1987)113:2(216).

Tribbia, John and Susanne C. Moser (June 2008). "More than information: what coastal managers need to plan for climate change". In: *Environmental Science and Policy* 11 (4), pp. 315–328. ISSN: 14629011. DOI: 10.1016/j.envsci.2008.01.003.

UK, Cavatorta (May 2021). *Gabion basket - Cavatorta UK*. URL: https://www.cavatortagroup.com/product/gabion-basket/.

UNDP, United Nations Development Programme (2019). *Early Warning System (EWS) Standard Operating Procedures — Cambodia — UNDP Climate Change Adaptation*. URL: https://www.adaptation-undp.org/Cambodia-EWS-standard-operating-procedures.

UNFCCC (2022). *Adaptation and Resilience*. URL: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction.

UNISDR, United Nations International Strategy for Disaster Reduction (2009). *UNISDR Terminology on Disaster Risk Reduction*. URL: https://www.preventionweb.net/files/7817_UNISDRTerminologyEnglish.pdf.

USACE, US Army Corps of Engineers (2003). *Glossary of coastal terminology*. Tech. rep. EM 1110-2-1100. URL: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1100_App_A.pdf.

— (n.d.). *US Army Corps of Engineers (USACE) Publications - Engineer Manuals*. URL: https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/u43544q/636F617374616C20656E67696E656

Utmani, Ritika (2021). "How can Circular Strategies be Implemented in Real Estate Valuation Practices". Available at https://repository.tudelft.nl/islandora/object/uuid:4ad33dc3-46eb-4541-a107-8dd5cf2c3875?collection=education. Master thesis. Delft, NL: Delft University of Technology.

Vegh, Tibor and Ignace Beguin (June 7, 2022). *A guide to private sector investment in coastal resilience - Climate Champions*. URL: https://climatechampions.unfccc.int/a-guide-to-private-sector-investment-in-coastal-resilience/.

Ware, Daniel and Zsuzsa Banhalmi-Zakar (Dec. 2020). "Strategies for governments to help close the coastal adaptation funding gap". In: *Ocean and Coastal Management* 198. ISSN: 09645691. DOI: 10.1016/j.ocecoaman.2020.105223.

White, Casey M., Sangeeta Mangubhai, Lukas Rumetna, and Cassandra M. Brooks (July 2022). "The bridging role of non-governmental organizations in the planning, adoption, and management of the marine protected area network in Raja Ampat, Indonesia". In: *Marine Policy* 141. ISSN: 0308597X. DOI: 10.1016/j.marpol.2022.105095.

Wiegmann, Paul Moritz, Henk J de Vries, and Knut Blind (2017). "Multi-mode standardisation: A critical review and a research agenda". In: *Research Policy* 46.8, pp. 1370–1386.

Winter, Gundula et al. (Mar. 2020). "Steps to Develop Early Warning Systems and Future Scenarios of Storm Wave-Driven Flooding Along Coral Reef-Lined Coasts". In: *Frontiers in Marine Science* 7. ISSN: 22967745. DOI: 10.3389/fmars.2020.00199.

A. Appendix A

A.1. Human research ethics checklist for human research

Delft University of Technology
HUMAN RESEARCH ETHICS
CHECKLIST FOR HUMAN RESEARCH
(Version January 2022)

IMPORTANT NOTES ON PREPARING THIS CHECKLIST

1. An HREC application should be submitted for every research study that involves human participants (as Research Subjects) carried out by TU Delft researchers
2. Your HREC application should be submitted and approved **before** potential participants are approached to take part in your study
3. All submissions from Master's Students for their research thesis need approval from the relevant Responsible Researcher
4. The Responsible Researcher must indicate their approval of the completeness and quality of the submission by signing and dating this form OR by providing approval to the corresponding researcher via email (included as a PDF with the full HREC submission)
5. There are various aspects of human research compliance which fall outside of the remit of the HREC, but which must be in place to obtain HREC approval. These often require input from internal or external experts such as Faculty Data Stewards, Faculty HSE advisors, the TU Delft Privacy Team or external Medical research partners.
6. You can find detailed guidance on completing your HREC application here
7. Please note that incomplete submissions (whether in terms of documentation or the information provided therein) will be returned for completion **prior to any assessment**
8. If you have any feedback on any aspect of the HREC approval tools and/or process you can leave your comments here

I. Applicant Information

PROJECT TITLE:	**Exploring consensus to develop global standards in response to Sea Level Rise (SLR)**
Research period: *Over what period of time will this specific part of the research take place*	**04-2023 to 08-2023**
Faculty:	**TPM**
Department:	**Values Technology and Innovation**
Type of the research project: *(Bachelor's, Master's, DreamTeam, PhD, PostDoc, Senior Researcher, Organisational etc.)*	**Master's**
Funder of research: *(EU, NWO, TUD, other – in which case please elaborate)*	**-**
Name of Corresponding Researcher: *(If different from the Responsible Researcher)*	**Mohammed Zeeshan S Jamadar**
E-mail Corresponding Researcher: *(If different from the Responsible Researcher)*	**m.z.s.jamadar@student.tudelft.nl**
Position of Corresponding Researcher: *(Masters, DreamTeam, PhD, PostDoc, Assistant/ Associate/ Full Professor)*	**Masters**
Name of Responsible Researcher: ***Note:** all student work must have a named Responsible Researcher to approve, sign and submit this application*	**Neelke Doorn**
E-mail of Responsible Researcher: *Please ensure that an institutional email address (**no Gmail, Yahoo, etc.**) is used for all project documentation/ communications including Informed Consent materials*	**N.Doorn@tudelft.nl**
Position of Responsible Researcher : *(PhD, PostDoc, Associate/ Assistant/ Full Professor)*	**Full Professor**

II. Research Overview

***NOTE:** You can find more guidance on completing this checklist here*

a) Please summarise your research very briefly (100-200 words)

What are you looking into, who is involved, how many participants there will be, how they will be recruited and what are they expected to do?

Add your text here – (please avoid jargon and abbrevations)
This research aims to identify the adaptation techniques that should be globally standardised in response to Sea Level Rise (SLR) using the Delphi method. The activities of the Delphi method are much similar to the process of developing standards and mainly rely on forming consensus. The method can guide the future standardisation process by creating a panel of experts (such as academicians) and stakeholders (such as decision-makers). The method operates in rounds. Each round involves a set of questionnaires that will be shared, analysed and reframed in subsequent rounds of the Delphi process until consensus is reached on standardising SLR adaptation techniques. The participants are required to answer these questions based on their expertise and are also allowed to review or change their answers over subsequent rounds. They would also receive an anonymised summary of the total responses. Once consensus is reached, the results will also be shared with the participants. The size of the panel will be around 20-30 participants that will be recruited by sending emails. The research is funded internally, and there are no research partners.

b) **If your application is an additional project** related to an existing approved HREC submission, please provide a brief explanation including the existing relevant HREC submission number/s.

Add your text here – (please avoid jargon and abbrevations)
-

c) **If your application is a simple extension of, or amendment to,** an existing approved HREC submission, you can simply submit an HREC Amendment Form as a submission through LabServant.

III. Risk Assessment and Mitigation Plan

NOTE: *You can find more guidance on completing this checklist here*

Please complete the following table in full for all points to which your answer is "yes". Bear in mind that the vast majority of projects involving human participants as Research Subjects also involve the collection of **Personally Identifiable Information (PII)** and/or **Personally Identifiable Research Data (PIRD)** which may pose potential risks to participants as detailed in Section G: Data Processing and Privacy below.

To ensure alignment between your risk assessment, data management and what you agree with your Research Subjects you can use the last two columns in the table below to refer to specific points in your Data Management Plan (DMP) and Informed Consent Form (ICF) – **but this is not compulsory**.

It's worth noting that **you're much more likely to need to resubmit your application if you neglect to identify potential risks**, than if you identify a potential risk and demonstrate how you will mitigate it. If necessary, the HREC will always work with you and colleagues in the Privacy Team and Data Management Services to see how, if at all possible, your research can be conducted.

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
A: Partners and collaboration						
1. Will the research be carried out in collaboration with additional organisational partners such as: • One or more collaborating research and/or commercial organisations • Either a research, or a work experience internship provider[1] [1] *If yes, please include the graduation agreement in this application*		x				
2. Is this research dependent on a Data Transfer or Processing Agreement with a collaborating partner or third party supplier? *If yes please provide a copy of the signed DTA/DPA*		x				
3. Has this research been approved by another (external) research ethics committee (e.g.: HREC and/or MREC/METC)? *If yes, please provide a copy of the approval (if possible) and summarise any key points in your Risk Management section below*		x				
B: Location						

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
4. Will the research take place in a country or countries, other than the Netherlands, within the EU?	x		With Sea Level Rise being a global phenomenon, there is a need to involve experts from all the over the world. This leads to a risk of English language being a communication barrier. As a result, a poor consent form understanding is also a risk.	Since the involved participants are international experts expected to know English well. Furthermore the informed consent form will be shared in as simple English as possible.		
5. Will the research take place in a country or countries outside the EU?	x		With Sea Level Rise being a global phenomenon, there is a need to involve experts from all the over the world. This leads to a risk of English language being a communication barrier. As a result, a poor consent form understanding is also a risk.	Since the involved participants are international experts expected to know English well. Furthermore the informed consent form will be shared in as simple English as possible.		
6. Will the research take place in a place/region or of higher risk – including known dangerous locations (in any country) or locations with non-democratic regimes?		x				
C: Participants						
7. Will the study involve participants who **may** be vulnerable and possibly (legally) unable to give informed consent? (e.g., children below the legal age for giving consent, people with learning difficulties, people living in care or nursing homes,).		x				
8. Will the study involve participants who **may** be vulnerable under specific circumstances and in specific contexts, such as victims and witnesses of violence, including domestic violence; sex workers; members of minority groups, refugees, irregular migrants or dissidents?		x				
9. Are the participants, outside the context of the research, in a dependent or subordinate position to the investigator (such as own children, own students or employees of either TU Delft and/or a collaborating partner organisation)? *It is essential that you safeguard against possible adverse consequences of this situation (such as allowing a student's failure to participate to your satisfaction to affect your evaluation of their coursework).*		x				
10. Is there a high possibility of re-identification for your participants? (e.g., do they have a very specialist job of which there are only a small number in a given country, are they members of a small community, or employees from a partner company collaborating in the research? Or are they one of only a handful of (expert) participants in the study?	x		The expert diaspora for adaptation techniques and Sea level rise related policies is a small circle of individuals that are active in public domain. The views expressed as a part of the study could potentially be linked back to their identities. Furthermore, as some of the sea level rise adaptation techniques are politically driven, any	Only the particpants who concur with informed consent will be taking part in the study with an option to withdraw from it being always available. The results presented would be anonymized as the main goal is to obtain consensus on the adaptation techniques that should be standardized. Thus, there is no possibility of backtracking the experts who support or oppose a particular technique. The overarching		

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
			departure from popular opinion of these experts poses a risk of public criticism.	principle of standardization itself is the voluntary nature of using standards. Therefore, there is no element of compulsion in acceptance towards the general public.		
D: Recruiting Participants						
11. Will your participants be recruited through your own, professional, channels such as conference attendance lists, or through specific network/s such as self-help groups		**x**				
12. Will the participants be recruited or accessed in the longer term by a (legal or customary) gatekeeper? (e.g., an adult professional working with children; a community leader or family member who has this customary role – within or outside the EU; the data producer of a long-term cohort study)		**x**				
13. Will you be recruiting your participants through a crowd-sourcing service and/or involve a third party data-gathering service, such as a survey platform?		**x**				
14. Will you be offering any financial, or other, remuneration to participants, and might this induce or bias participation?		**x**				
E: Subject Matter *Research related to medical questions/health may require special attention. See also the website of the CCMO before contacting the HREC.*						
15. Will your research involve any of the following: • Medical research and/or clinical trials • Invasive sampling and/or medical imaging • Medical and *In Vitro Diagnostic Medical* Devices Research		**x**				
16. Will drugs, placebos, or other substances (e.g., drinks, foods, food or drink constituents, dietary supplements) be administered to the study participants? *If yes see here to determine whether medical ethical approval is required*		**x**				
17. Will blood or tissue samples be obtained from participants? *If yes see here to determine whether medical ethical approval is required*		**x**				
18. Does the study risk causing psychological stress or anxiety beyond that normally encountered by the participants in their life outside research?		**x**				
19. Will the study involve discussion of personal sensitive data which could put participants at increased legal, financial, reputational, security or other risk? (e.g., financial data, location data, data relating to children or other vulnerable groups)		**x**				

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
Definitions of sensitive personal data, and special cases are provided on the TUD Privacy Team website.						
20. Will the study involve disclosing commercially or professionally sensitive, or confidential information? (e.g., relating to decision-making processes or business strategies which might, for example, be of interest to competitors)		x				
21. Has your study been identified by the TU Delft Privacy Team as requiring a Data Processing Impact Assessment (DPIA)? *If yes please attach the advice/ approval from the Privacy Team to this application*		x				
22. Does your research investigate causes or areas of conflict? *If yes please confirm that your fieldwork has been discussed with the appropriate safety/security advisors and approved by your Department/Faculty.*		x				
23. Does your research involve observing illegal activities or data processed or provided by authorities responsible for preventing, investigating, detecting or prosecuting criminal offences *If so please confirm that your work has been discussed with the appropriate legal advisors and approved by your Department/Faculty.*		x				
F: Research Methods						
24. Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g., covert observation of people in non-public places).		x				
25. Will the study involve actively deceiving the participants? (For example, will participants be deliberately falsely informed, will information be withheld from them or will they be misled in such a way that they are likely to object or show unease when debriefed about the study).		x				
26. Is pain or more than mild discomfort likely to result from the study? And/or could your research activity cause an accident involving (non-) participants?		x				
27. Will the experiment involve the use of devices that are not 'CE' certified? *Only, if 'yes': continue with the following questions:*		x				
• Was the device built in-house?						
• Was it inspected by a safety expert at TU Delft? *If yes, please provide a signed device report*						

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
• If it was not built in-house and not CE-certified, was it inspected by some other, qualified authority in safety and approved? *If yes, please provide records of the inspection*						
28. Will your research involve face-to-face encounters with your participants and if so how will you assess and address Covid considerations?		**x**				
29. Will your research involve **either:** a) "big data", combined datasets, new data-gathering or new data-merging techniques which might lead to re-identification of your participants **and/or** b) artificial intelligence or algorithm training where, for example biased datasets could lead to biased outcomes?		**x**				
G: Data Processing and Privacy						
30. Will the research involve collecting, processing and/or storing any directly identifiable PII (Personally Identifiable Information) including name or email address that will be used for administrative purposes only? (eg: obtaining Informed Consent or disbursing remuneration)	**x**		Owing to the requirement of backtracking the participants for subsequent rounds of the Delphi technique, the Personally Identifiable Information (PII)will be collected in the online survey. This being on an online platforms creates a risk of data leaks and consequently revealing the identities of the individuals.	The data will be stored on secured OneDrive and Qualtrics platform with access only to the corresponding researcher and the thesis committee. The personal data of each of the participant will be linked to a unique identifier number for backtracking.		
31. Will the research involve collecting, processing and/or storing any directly or indirectly identifiable PIRD (Personally Identifiable Research Data) including videos, pictures, IP address, gender, age etc and **what other Personal Research Data** (including personal or professional views) will you be collecting?		**x**				
32. Will this research involve collecting data from the internet, social media and/or publicly available datasets which have been originally contributed by human participants		x				
33. Will your research findings be published in one or more forms in the public domain, as e.g., Masters thesis, journal publication, conference presentation or wider public dissemination?	**x**		The research will be presented to the thesis committee at the end. The thesis document generated will be available at the TU Delft education repository for future reference. This being available on the internet poses a risk of exposing PII and Personally Identifiable Research Data (PIRD) of the particpants to be traced through their previous affiliations.	There is a provision of informed consent to all the particpants. The PII will be deleted soon after the study is over. The PIRD will be anonymised and stored in the secured TU Delft server (data4tu.nl) with access only to the responsible researchers.		
34. Will your research data be archived for re-use and/or teaching in an open, private or semi-open archive?	**x**		The data will be stored on secured TU Delft server with access to responsible researchers, this leads to	All the columns containing personal information will be deleted from excel. All the answers shared by the participants will be reviewed to check if any personal		

			If YES please complete the Risk Assessment and Mitigation Plan columns below.		*Please provide the relevant reference #*	
ISSUE	**Yes**	**No**	**RISK ASSESSMENT – what risks could arise?** *Please ensure that you list ALL of the actual risks that could potentially arise – do not simply state whether you consider any such risks are important!*	**MITIGATION PLAN – what mitigating steps will you take?** *Please ensure that you summarise what actual mitigation measures you will take for each potential risk identified – do not simply state that you will e.g. comply with regulations.*	**DMP**	**ICF**
			a risk of accidentally revealing the identity of the participants.	information is inadvertently shared and will also be deleted.		

H: More on Informed Consent and Data Management

NOTE: *You can find guidance and templates for preparing your Informed Consent materials) here*

Your research involves human participants as Research Subjects if you are recruiting them or actively involving or influencing, manipulating or directing them in any way in your research activities. This means you must seek informed consent and agree/ implement appropriate safeguards regardless of whether you are collecting any PIRD.

Where you are also collecting PIRD, and using Informed Consent as the legal basis for your research, you need to also make sure that your IC materials are clear on any related risks and the mitigating measures you will take – including through responsible data management.

Got a comment on this checklist or the HREC process? You can leave your comments here

IV. Signature/s

Please note that by signing this checklist list as the sole, or Responsible, researcher you are providing approval of the completeness and quality of the submission, as well as confirming alignment between GDPR, Data Management and Informed Consent requirements.

Name of Corresponding Researcher (if different from the Responsible Researcher) (print)

Signature of Corresponding Researcher: Mohd Zeeshan S Jamadar

Date:17 April, 2023

Name of Responsible Researcher (print)

Signature (or upload consent by mail) Responsible Researcher: Neelke Doorn

Date: 17 April, 2023

V. Completing your HREC application

Please use the following list to check that you have provided all relevant documentation

Required:

- **Always:** This completed HREC checklist
- **Always:** A data management plan (reviewed, where necessary, by a data-steward)
- **Usually:** A complete Informed Consent form (including Participant Information) and/or Opening Statement (for online consent)

Please also attach any of the following, if relevant to your research:

Document or approval	Contact/s
Full Research Ethics Application	After the assessment of your initial application **HREC will let you know if and when you need to submit additional information**
Signed, valid Device Report	Your Faculty HSE advisor
Ethics approval from an external Medical Committee	TU Delft Policy Advisor, Medical (Devices) Research
Ethics approval from an external Research Ethics Committee	Please append, if possible, with your submission
Approved Data Transfer or Data Processing Agreement	Your Faculty Data Steward and/or TU Delft Privacy Team
Approved Graduation Agreement	Your Master's thesis supervisor
Data Processing Impact Assessment (DPIA)	TU Delft Privacy Team
Other specific requirement	Please reference/explain in your checklist and append with your submission

A.2. Data Management Plan (DMP)

Plan Overview

A Data Management Plan created using DMPonline

Title: Exploring consensus to develop global standards in response to Sea Level Rise (SLR)

Creator: Mohammed Zeeshan Shadahmed Jamadar

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

Project abstract:

The ongoing climate crisis and the current carbon emissions levels have resulted in irreversible sea level rise (SLR); thus, SLR is inevitable. Adaptation against the SLR is the most viable option to save coastal areas from adverse impacts. There is a widespread acceptance that the decision-making process associated with SLR adaptations suffers from a lack of information, poor coordination among stakeholders and outdated standards that do not stand up against rising sea levels. Furthermore, the multitude of adaptation techniques available causes a problem for policymakers. As a result, there is an urgent need for a global collective strategy to address SLR. Standardisation is an apt solution to these problems as it seeks to provide a common solution and adopt the best practices across the globe. This research aims to identify the adaptation techniques that could be globally standardised in response to Sea Level Rise (SLR) using the Delphi technique.

ID: 119204

Start date: 20-03-2023

End date: 14-08-2023

Last modified: 18-04-2023

Exploring consensus to develop global standards in response to Sea Level Rise (SLR)

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty data steward, Nicolas Dintzner, has reviewed this DMP on 07/03/2023.

2. Date of consultation with support staff.

2023-03-07

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Survey questions	.csv files	Formulated as a part of the research as well as generated as feedback from participants in the online survey	To understand expert opinion on the possibilities of standardising sea level rise adaptation measures	OneDrive and Qualtrics	Zeeshan Jamadar, Martijn Wiarda, Geerten van de Kaa and Neelke Doorn
List of participants	.csv files	As a part of the online survey the participants would be asked to share their names	To contact the participants again for the subsequent rounds of the Delphi process	OneDrive and Qualtrics	Zeeshan Jamadar, Martijn Wiarda, Geerten van de Kaa and Neelke Doorn
Results of the survey	.csv files	The inputs provided by the participants in the online survey	To formulate the results of the study i.e. to evaluate the consensus about sea level rise adaptation measures	OneDrive and Qualtrics	Zeeshan Jamadar, Martijn Wiarda, Geerten van de Kaa and Neelke Doorn

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Data will be deposited in a data repository at the end of the project (see section V) and data discoverability and re-usability will be ensured by adhering to the repository's metadata standards
- README file or other documentation explaining how data is organised
- Methodology of data collection

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- Another storage system - please explain below, including provided security measures
- OneDrive

Qualtrics

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, ask your Faculty Data Steward for advice. You can also check with the privacy website or contact the privacy team: privacy-tud@tudelft.nl

- Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question. If this is not the case, you can use the example below.

The research forms part of an internal TU Delft Master's thesis (i.e. student project). During the active phase, the data will only be accessible to the corresponding researcher (i.e. me) and the research committee. Barring the personal information of the participants, the results will be published with the successful completion of the thesis requirements of Tu Delft in the educational repository of TU Delft.

10. Which personal data will you process? Tick all that apply

- Other types of personal data - please explain below
- Email addresses and/or other addresses for digital communication
- Names and addresses

As the Delphi process relies on the experts' opinions, it is necessary to classify all the participants based on their expertise and obtain the same information from the participants. However, to eliminate any possibilities of these being specific to the point that the identity of a participant might get compromised, open-ended questions will not be asked. Instead, a set of general options would be given to participants as a part of the survey. The options such as researcher, government executive, corporate expert etc, would be used.

11. Please list the categories of data subjects

Experts in the domain of coastal adaptation strategies would form the part of data subjects. These shall include professionals such as:
1. Academicians
2. Decision-makers
3. Industrial experts

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

All the participants would be subjected to an opening statement seeking their informed consent as part of the online survey. There will be a check box provided to obtain their approval.

17. Where will you store the signed consent forms?

- Other - please explain below

As the consent form is a part of the online survey, the results obtained at the end of the survey will have the consent forms. During the active phase of the project, these will be stored in OneDrive and Qualtrics. The personal data column is not part of the research data as this will be deleted.

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).
If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.
If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.
If you have any additional comments, please add them in the box below.

- None of the above applies

22. What will happen with personal research data after the end of the research project?

- Personal research data will be destroyed after the end of the research project
- Anonymised or aggregated data will be shared with others

The list of participants and names collected in the survey will be deleted at the end of the research.

23. How long will (pseudonymised) personal data be stored for?

- Other - please state the duration and explain the rationale below

For the duration of the Master's thesis project.

24. What is the purpose of sharing personal data?

- Other - please explain below

We will not be sharing the personal data.

25. Will your study participants be asked for their consent for data sharing?

- Yes, in consent form - please explain below what you will do with data from participants who did not consent to data sharing

Opening statement of the survey will contain the consent form.

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- All other non-personal data (and code) underlying published articles / reports / theses

29. How will you share research data (and code), including the one mentioned in question 22?

- All anonymised or aggregated data, and/or all other non-personal data will be uploaded to 4TU.ResearchData with public access

30. How much of your data will be shared in a research data repository?

- < 100 GB

31. When will the data (or code) be shared?

- At the end of the research project

32. Under what licence will be the data/code released?

- CC BY

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

The following persons shall be responsible for the data:

Name	Position	Role in Thesis Committee	Email id
Neelke Doorn	Full Professor	Chairperson	N.Doorn@tudelft.nl
Geerten van de Kaa	Associate Professor	Thesis Supervisor	g.vandekaa@tudelft.nl
Martijn Wiarda	PhD Candidate	Thesis Advisor	M.J.Wiarda@tudelft.nl

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

None (NA)

A.3. Informed consent

Informed Consent Forms

The informed consent form was shared in each round. Below are the forms for each of the rounds in a sequence:

Informed Consent form for Delphi Round 1

Welcome to the Research Study on Sea Level Rise Adaptation Standards!

You are invited to participate in the research **'to explore consensus on what areas of Sea Level Rise (SLR) adaptations could be globally standardised'** by TU Delft, the Netherlands. The study will take place in multiple short rounds between April 2023 and August 2023.

This is the first round of the study, comprising a short 5-minute questionnaire. After each round, you will receive a summary of the results and a new questionnaire. The study will conclude when consensus amongst respondents is reached. Results may be used for future SLR adaptation and standardisation studies and will be publicly available in TU Delft's educational repository. As an expert in the field, participating in this study is entirely voluntary, and you can withdraw anytime.

Your answers will remain confidential. We will minimise risks by anonymising and securely storing data at TU Delft during the study. By participating in this survey, you agree to these conditions.

We thank you for your valuable participation in the first round of our study.

Zeeshan Jamadar, m.z.s.jamadar@tudelft.nl
Prof. Neelke Doorn, n.doorn@tudelft.nl
TU Delft

[If participants agree to this Opening Statement by clicking through to an (anonymous) online survey, they will be subjected to the entire study]

Informed Consent form for Delphi Round 2

Welcome to the Research Study on Sea Level Rise Adaptation Standards!

You are invited to participate in the research **'to explore consensus on what areas of Sea Level Rise (SLR) adaptations could be globally standardised'** by TU Delft, the Netherlands. The study will take place in multiple short rounds between April 2023 and August 2023.

This is the second, and probably the final round of the study, comprising a short summary of the results of the first round of our study followed by a newer 5-minute questionnaire. After the round, you will receive a summary of the results. The study will conclude when consensus amongst respondents is reached. Results may be used for future SLR adaptation and standardisation studies and will be publicly available in TU Delft's educational repository. As an expert in the field, participating in this study is entirely voluntary, and you can withdraw anytime.

Your answers will remain confidential. We will minimise risks by anonymising and securely storing data at TU Delft during the study. By participating in this survey, you agree to these conditions.

We thank you for your valuable participation in the second round of our study.

Zeeshan Jamadar, m.z.s.jamadar@tudelft.nl
Prof. Neelke Doorn, n.doorn@tudelft.nl
TU Delft

[If participants agree to this Opening Statement by clicking through to an (anonymous) online survey, they will be subjected to the entire study]

B. Appendix B

B.1. Email invites

1. **Round 1 invite**

   Dear Sir/Madam,

   I hope this email finds you well.

   I am conducting a research study on sea level rise adaptation measures, and I am seeking the opinions of experts in this field. As a leading professional in this area, your insights would be invaluable to the success of this study.

   The purpose of this study is to explore the global standardisation of adaptation measures in response to sea level rise. Your participation will involve completing a short survey, which will take approximately 5 minutes.

   Your input will help to create a more comprehensive understanding of the specific adaptation measures that could benefit from standardisation.

   The study is being conducted at TU Delft, and your responses will remain anonymous.

   If you are interested in participating, please click on the following link to access the survey: *(Survey hyperlink here)*

   Or copy and paste the URL below into your Internet browser: *(Survey link here)*

   Please feel free to share this invitation with your colleagues who may also be interested in participating.

   Thank you in advance for your consideration and time.

   Best regards,
   Zeeshan Jamadar (m.z.s.jamadar@tudelft.nl)
   Prof. Neelke Doorn (n.doorn@tudelft.nl)

2. **Round 2 invite (for R1 participants)**

   Dear Sir/Ma'am,

   We thank you for your valuable participation in round 1 of our research on sea level rise adaptation standards. The study aims to identify sea level rise adaptation measures that could be globally standardised.

   We are happy to share with you the summary of the results of round 1. Based on the results of round 1, we have a newer questionnaire that will help us reach a consensus on sea level rise adaptation standardisation. Your participation will involve completing a short 5-minutes survey. This will most probably be the final round of our study.

   The study is being conducted at TU Delft and your responses will remain anonymous.

   Please click on the link below to access the survey and the summary of the results: *(Survey hyperlink here)*

   Or copy and paste the URL below into your Internet browser: *(Survey link here)*

   Please feel free to reach out to us if you have any questions or suggestions.

Thank you in advance for your time and consideration.

Kind regards,
Zeeshan Jamadar (m.z.s.jamadar@tudelft.nl)
Prof. Neelke Doorn (n.doorn@tudelft.nl)

3. **Round 2 invite (for new participants)**

   Dear Sir/Ma'am,

   We have successfully completed the first round of our research on sea level rise adaptation standards. The study aims to identify sea level rise adaptation measures that could be globally standardised. The results of our first round of study are intriguing and we would improve on it with your participation in the second round of the study.

   We are happy to share with you the summary of the results of round 1. Based on the results of round 1, we have a newer questionnaire that will help us reach a consensus on sea level rise adaptation standardisation. Your participation will involve completing a short 5-minutes survey. This will most probably be the final round of our study.

   The study is being conducted at TU Delft and your responses will remain anonymous.

   Please click on the link below to access the survey and the summary of the results: *(Survey hyperlink here)*

   Or copy and paste the URL below into your Internet browser: *(Survey link here)*

   Please feel free to reach out to us if you have any questions or suggestions.

   Thank you in advance for your time and consideration.

   Best regards,
   Zeeshan Jamadar (m.z.s.jamadar@tudelft.nl)
   Prof. Neelke Doorn (n.doorn@tudelft.nl)

B.2. LinkedIn invites

1. 300-character invite message

   Dear [Recipient's Name],

   I'm conducting a research survey at TU Delft to explore the global standardisation of adaptation measures for sea level rise. Your expertise in this field would be invaluable. Would you be willing to participate?

   (Survey link here)

   Thanks!

2. Connected participants invite message

   Dear [Recipient's Name],

   Research Survey on Sea Level Rise Adaptation Standards

   I hope this message finds you well. I am reaching out to invite you to participate in a study that I am conducting on sea level rise adaptation measures, and I am seeking the opinions of experts in this field. As a leading professional in this area, your insights would be invaluable to the success of this study.

   The purpose of this study is to explore the global standardisation of adaptation measures in response to sea level rise. Your participation will involve completing a short survey, which will take approximately 5 minutes.

Your input will help to create a more comprehensive understanding of the specific adaptation measures that could benefit from standardisation.

If you are interested in participating, please click on the following link to access the survey: *(Survey hyperlink here)*

Please note that your participation in this study is entirely voluntary, and all responses will remain anonymous and confidential.

Please feel free to share this invitation with your colleagues who may also be interested in participating.

Thank you for your time and consideration, and I hope to hear from you soon.

Best regards,
Zeeshan Jamadar
m.z.s.jamadar@tudelft.nl

C. Appendix C

C.1. Round 1 questionnaire

TU Delft

Informed Consent

Welcome to the Research Study on Sea Level Rise Adaptation Standards!

You are invited to participate in the research **'to explore consensus on what areas of Sea Level Rise (SLR) adaptations could be globally standardised'** by TU Delft, the Netherlands. The study will take place in multiple short rounds between April 2023 and August 2023.

This is the first round of the study, comprising a short 5-minute questionnaire. After each round, you will receive a summary of the results and a new questionnaire. The study will conclude when consensus amongst respondents is reached. Results may be used for future SLR adaptation and standardisation studies and will be publicly available in TU Delft's educational repository. As an expert in the field, participating in this study is entirely voluntary, and you can withdraw anytime.

Your answers will remain confidential. We will minimise risks by anonymising and securely storing data at TU Delft during the study. By participating in this survey, you agree to these conditions.

We thank you for your valuable participation in the first round of our study.

Zeeshan Jamadar, m.z.s.jamadar@tudelft.nl

Prof. Neelke Doorn, n.doorn@tudelft.nl

TU Delft

- ○ I consent, begin the study
- ○ I do not consent, I do not wish to participate

Expert Information

Personal Information

First Name

Last Name

Please enter your email address

Please specify your country of origin

Optional

${q://QID12/ChoiceTextEntryValue/1}, what type of organisation are you mainly affiliated with? Select any one.

Optional

- Private Sector
- Government
- International/Multilateral Organisation such as the UN, OECD, World Bank, EU etc.
- Non Governmental Organisation (NGO)
- Academic/Research Institute
- Other (please specify)

What describes your experience level in coastal adaptation the best?

- Non-expert
- Junior-level (1-3 years)
- Mid-level (3-8 years)
- Senior-level (>8 years)

Research Context

Research Context

Sea Level Rise (SLR) adaptation aims at reducing the impacts of SLR via behavioural changes, beginning with individual actions and ranging to collective coastal management policy. **The global standards for SLR adaptation measures are yet to be developed.**

Standardisation involves developing and implementing uniform guidelines, protocols, and procedures for planning, designing, and implementing measures to adapt to sea level rise impacts. This includes standardising technical specifications, performance criteria, monitoring and evaluation frameworks, and decision-making processes.

Standardisation will ensure that adaptation measures are consistent, efficient, effective, and based on best practices and the latest scientific knowledge. Thus, SLR adaptation standards will help enhance comparability, transparency, and accountability across different regions and sectors, promoting collaboration, learning, and innovation.

The objective of the research is to identify those adaptation measures that could be globally standardised.

Measures for Standardisation

Which of the following specific adaptation measures do you think could be globally standardised? Select all that apply.

- [ ] Elevating buildings and infrastructure
- [ ] Community capacity building
- [ ] Dikes
- [ ] Piers
- [ ] Sandbags
- [ ] Coastal dams
- [ ] Beach nourishment
- [ ] Dune restoration
- [ ] Horizontal planned retreat
- [ ] Mangroves
- [ ] Wetlands
- [ ] Migration of communities
- [ ] Vegetated buffers

- [ ] Jetties
- [ ] Integrated coastal zone management (ICZM)
- [ ] Ports
- [ ] Land reclamation
- [ ] Breakwaters
- [ ] Upgrading drainage and stormwater systems
- [ ] Gabion basket and mesh rubble
- [ ] Early warning systems
- [ ] Levees
- [ ] Revetments
- [ ] Adaptation planning
- [ ] Seawalls
- [ ] Community capacity building
- [ ] Hazard and vulnerability assessment
- [ ] Groynes
- [ ] Flood and storm surge barriers
- [ ] _____ Other (please specify)
- [ ] _____ Other (please specify)
- [ ] _____ Other (please specify)
- [ ] None of the measures could be standardised

Why these SLR adaptation measures could be standardised?

» Dikes _____
» Levees _____
» Seawalls _____
» Groynes _____
» Breakwaters _____
» Flood and storm surge barriers _____
» Coastal dams _____
» Revetments _____
» Jetties _____
» Sandbags _____
» Gabion basket and mesh rubble _____
» Beach nourishment _____
» Vegetated buffers _____

- Dune restoration
- Wetlands
- Mangroves
- Piers
- Ports
- Land reclamation
- Elevating buildings and infrastructure
- Upgrading drainage and stormwater systems
- Horizontal planned retreat
- Migration of communities
- Community capacity building
- Early warning systems
- Hazard and vulnerability assessment
- Integrated coastal zone management (ICZM)
- Community capacity building
- Adaptation planning
- Other (please specify)
- Other (please specify)
- Other (please specify)
- None of the measures could be standardised

Round 1

C.2. Round 2 questionnaire

TU Delft

Informed Consent

Welcome to the Research Study on Sea Level Rise Adaptation Standards!

You are invited to participate in the research **'to explore consensus on what areas of Sea Level Rise (SLR) adaptation could be globally standardised'** by TU Delft, the Netherlands. The study will take place in multiple short rounds between April 2023 and August 2023.

This is the second, and probably the final round of the study, comprising a short summary of the results of the first round of our study followed by a newer 5-minute questionnaire. After the round, you will receive a summary of the results. The study will conclude when consensus amongst respondents is reached. Results may be used for future SLR adaptation and standardisation studies and will be publicly available in TU Delft's educational repository. As an expert in the field, participating in this study is entirely voluntary, and you can withdraw anytime.

Your answers will remain confidential. We will minimise risks by anonymising and securely storing data at TU Delft during the study. By participating in this survey, you agree to these conditions.

We thank you for your valuable participation in the second round of our study.

Zeeshan Jamadar, m.z.s.jamadar@tudelft.nl

Prof. Neelke Doorn, n.doorn@tudelft.nl

TU Delft

○ I consent, begin the study

- ○ I do not consent, I do not wish to participate

Expert Information

Personal Information

First Name

Last Name

Please enter your email address

${q://QID12/ChoiceTextEntryValue/1}, have you participated in the first round of study?

- ○ Yes
- ○ No

Please specify your country of origin

Optional

${q://QID12/ChoiceTextEntryValue/1}, what type of organisation are you mainly affiliated with? Select any one.

Optional

- ○ Private Sector
- ○ Government
- ○ International/Multilateral Organisation such as the UN, OECD, World Bank, EU etc.
- ○ Non Governmental Organisation (NGO)
- ○ Academic/Research Institute
- ○ Other (please specify)

What describes your experience level in coastal adaptation the best?

- ○ Non-expert

- ○ Junior-level (1-3 years)
- ○ Mid-level (3-8 years)
- ○ Senior-level (>8 years)

Research Context

Research Context and Round 1 Summary

Sea Level Rise (SLR) adaptation aims at reducing the impacts of SLR via behavioural changes, beginning with individual actions and ranging to collective coastal management policy. **The global standards for SLR adaptation measures are yet to be developed.**

Standardisation involves developing and implementing uniform guidelines, protocols, and procedures for planning, designing, and implementing measures to adapt to sea level rise impacts. This includes standardising technical specifications, performance criteria, monitoring and evaluation frameworks, and decision-making processes.

Standardisation will ensure that adaptation measures are consistent, efficient, effective, and based on best practices and the latest scientific knowledge. Thus, SLR adaptation standards will help enhance comparability, transparency, and accountability across different regions and sectors, promoting collaboration, learning, and innovation.

The objective of the research is to identify those adaptation measures that could be globally standardised.

Please click here to see the summary of round 1 of the study.

None measures

Did you choose 'None of the measures could be standardised' in the first round of the study? Or do you think 'None of the measures could be standardised'?

- ○ Yes
- ○ No

Based on the results of round 1, would you like to reconsider your choice for 'None of the measures could be standardised'?

- Yes
- No

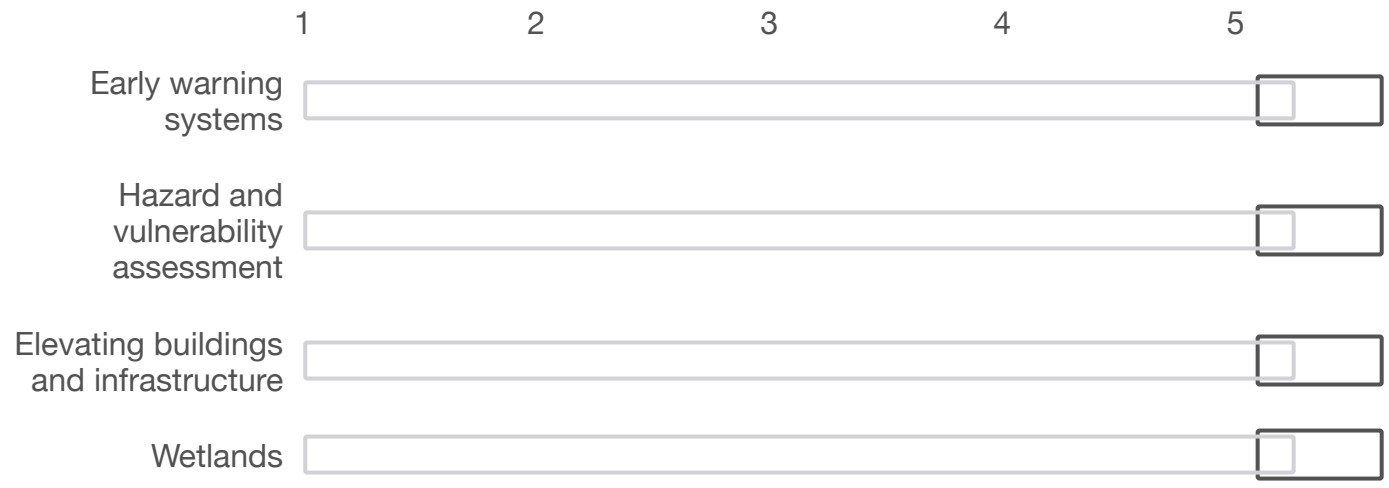
Measures that could be standardised

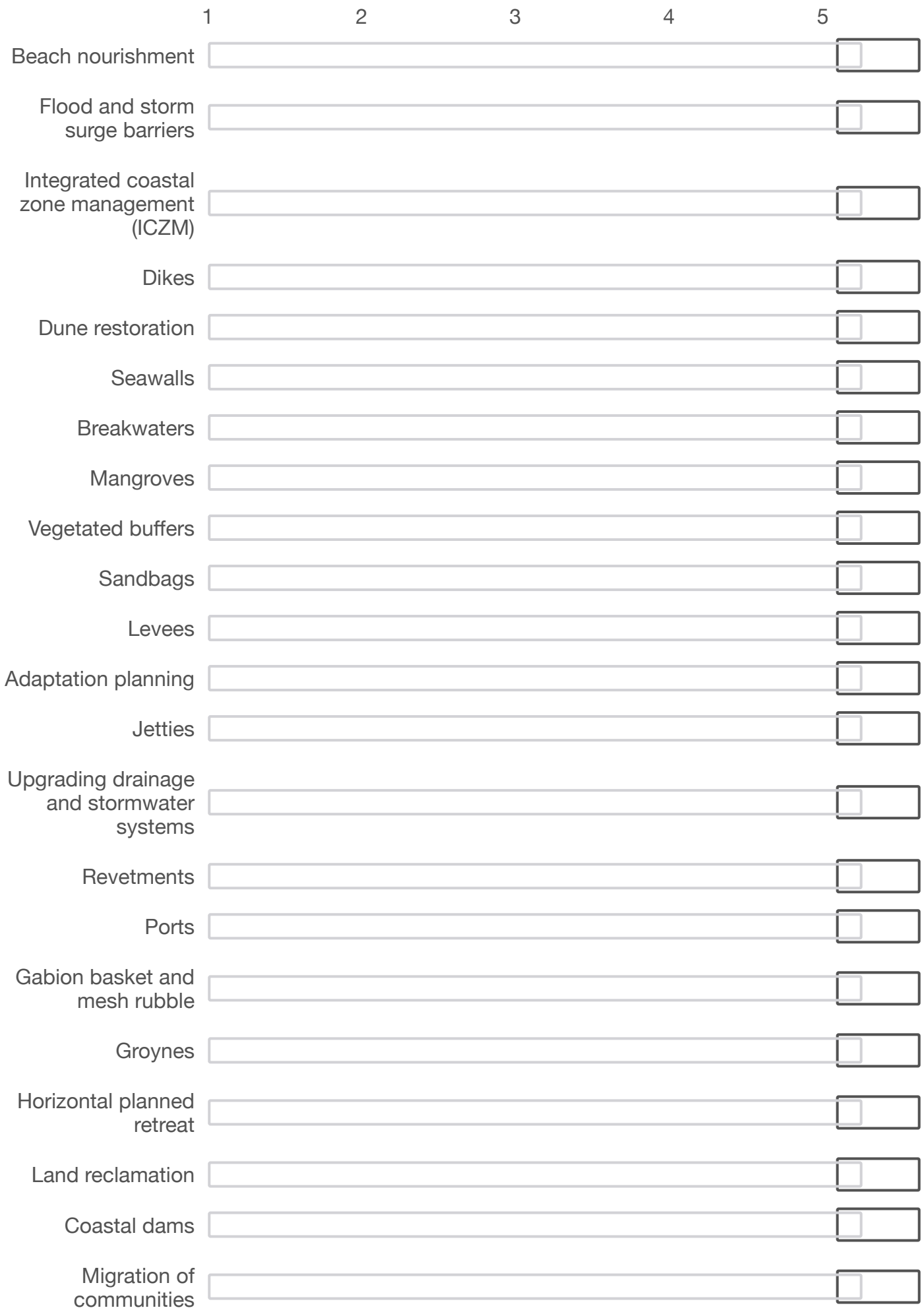
The following reasons have been identified for and against the standardisation of adaptation measures -

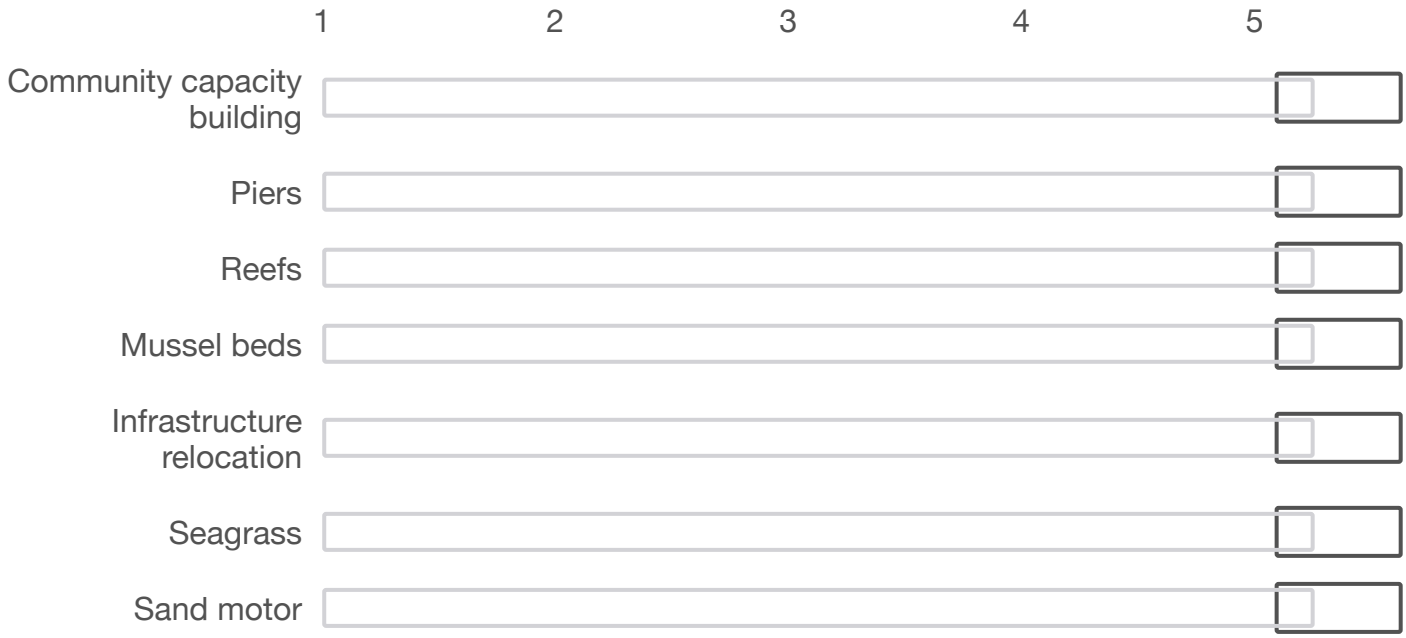
For Standardisation	Against Standardisation
a. Adaptation measure being engineering-based.	a. Location-specific design requirements for adaptation measures.
b. Availability of a pre-existing standard or methodology for an adaptation measure.	b. Variations in regional institutional and legal frameworks.
c. Possibility for data standards e.g. sharing, collection and interoperability.	c. Political uncertainty and cultural differences at various locations.

While keeping in mind the above factors, please rate the following sea level rise adaptation measures for their suitability to be globally standardised -

1 - Strongly Disagree
2 - Disagree
3 - Neutral
4 - Agree
5 - Strongly Agree




1
2
3
4
5
Beach nourishment
Flood and storm surge barriers
Integrated coastal zone management (ICZM)
Dikes
Dune restoration
Seawalls
Breakwaters
Mangroves
Vegetated buffers
Sandbags
Levees
Adaptation planning
Jetties
Upgrading drainage and stormwater systems
Revetments
Ports
Gabion basket and mesh rubble
Groynes
Horizontal planned retreat
Land reclamation
Coastal dams
Migration of communities



Rank order adaptation measures

Before we conclude, we would like to invite you to share any additional comments or feedback you may have. Please feel free to express any thoughts, concerns, suggestions, or ideas that you believe are relevant to sea level rise adaptation standardisation.

Round 2