Climate change adaptation in coastal cities of developing countries: characterizing types of vulnerability and adaptation options

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Abstract
Facing the increasingly adverse impacts of climate change, many coastal cities in developing and least-developed countries have shaped their climate adaptation plan. This study aims to unpack the state-of-the-art municipal adaptation planning in developing countries. The paper seeks to understand the types of vulnerability and explore planned adaptation options through a content analysis of adaptation planning documents in 45 selected coastal cities in developing countries. The result shows the complexity of vulnerabilities that are not only climate change impacts, but more importantly, the socio-economic sensitivity, the insufficient infrastructure system, and limited adaptive capacity. Adaptation responses, correspondingly, address primarily current vulnerabilities rather than future climate change impacts. Local climate change adaptation in developing countries, therefore, cannot separate from socio-economic development and capacity enhancement. A coordination mechanism for inter-policy is necessary to manage the trade-offs between multiple priorities.

Keywords Climate change · Coastal cities · Developing countries · Vulnerabilities · Adaptation options

1 Introduction
Climate change is likely unavoidable even with proactive practices in emission reduction. Although governments have committed to limiting global warming to 1.5 °C, the potential impacts of and the risks associated with climate change are still very high (Masson-Delmotte et al. 2018). Local communities, the first responders, will need adaptation actions to alleviate...
these impacts and risks. Many local municipalities have conducted adaptation planning to assess current and future vulnerabilities, potential climate change impacts, and identify actions to adapt to variability in the future. Tracking the practices of climate change adaptation (CCA) planning is necessary to offer interactive lessons between theory and practices. These studies, as reported in the literature, are primarily focused on developed countries (for instance, Baker et al. 2012; Baynham and Stevens 2014; Tang et al. 2010; Woodruff and Stults 2016) but few on developing and least-developed countries.

Local climate adaptation planning in developing countries was initiated relatively early with the city of Cape Town in 2006 (Mukheibir and Ziervogel 2007), the locally rooted adaptation strategy in Durban, South Africa (Roberts 2008), and become more prevalent given the international cooperation and assistance to the least-developed and developing countries (Dodman 2012; Tyler and Moench 2012). Studies of local climate adaptation plans, however, mainly focus on single cases, such as Broto et al. (2015); Button et al. (2013); and Wijaya (2015). Some offer an analytic comparison, for instance, urban governance for adaptation in ten Asian cities (Tanner et al. 2009) and the methodology of urban climate resilience planning in Indian cities (Sharma et al. 2013). Nonetheless, there is no study of municipal adaptation plans across multiple cities across developing countries.

Specifically, coastal cities in developing countries are increasingly susceptible to the adverse impacts of climate change due to a combination of climatic and non-climatic factors. Related studies diverge into three principal directions. The first track examines the global warming and increasing temperature having jeopardized water supply, food production and security, and human health to many regions across developing countries in Asia, Africa, Central, and South America (Hijioka et al. 2014; Magrine et al. 2014; Niang et al. 2014). The second track studied on the impacts of climate change to coastal cities and low-lying regions, which mainly focus on sea-level rise (SLR), flooding, erosion, storm, and typhoon (Balica et al. 2012; Boateng 2012; DiGregorio 2015; Finkl 2012; Nicholls 2010; Sales Jr 2009; Wong et al. 2014; Yan et al. 2016). With the scenario of 1-m sea-level rise (SLR), more than 50 million people in developing countries are likely to be displaced, accompanied by severe economic and ecological damage (Dasgupta et al. 2009). The third direction examines non-climatic factors, such as increasing urbanization, economic development, and entitlement to resources, which have exacerbated the vulnerability to coastal cities in developing countries (Adger 1999; Kelly and Adger 2000; Surjan et al. 2016). The complexity of vulnerability posed by climate change coupled with non-climatic factors, however, is not fully explored in coastal cities of developing countries.

As a sequence, while a body of literature has proposed various adaptation options for coastal systems and low-lying areas (Hale et al. 2009; Hill 2015; Klein et al. 2001; Tobey et al. 2010; U.S. EPA 2009; Wong et al. 2014), how coastal cities in different regions, especially in developing countries, respond to climate change impacts are not elaborated in existing literature. This study seeks to unpack the state-of-the-art of adaptation planning by characterizing the types of vulnerability and adaptation options in multiple coastal cities in developing countries. Specifically, the paper addresses three research questions: (1) What are the types of risks and vulnerabilities in coastal cities in developing countries? (2) What are the adaptation options and strategies formulated to respond to these vulnerabilities? (3) What is the status of adaptation planning in coastal cities of developing countries?
2 Framework for tracking coastal climate change adaptation planning in developing countries

In order to track adaptation planning in coastal cities of developing countries, this paper presents a framework allowing for comparative analysis. Adaptation tracking in this study will examine two main components of a generalized adaptation planning (Bierbaum et al. 2013): risk and vulnerability identification and formulated adaptation options and strategies to respond to these risks and vulnerabilities. The two phases represent the relationship of the problem—solution, in which the recognition of risks and vulnerabilities is crucial and an essential condition for the justification in the distribution of resources (Schlosberg 2012). Figure 1 is the conceptual framework of adaptation planning, in which the risks and vulnerability, caused by climate change and climate variability and the non-climatic factors, are the impetus for climate change adaptation.

Disaster risk refers to the probability of severe alterations in the regular operation of a community or society due to the incidence of hazardous physical events interacting with the vulnerable social condition. It is the function of hazard (weather and climate extremes), exposure, and social vulnerability (IPCC 2012).

Vulnerability of a community or society, which is the interaction between three main dimensions: exposure, sensitivity, and adaptive capacity, is affected by both weather and climate extremes (hazardous events) and non-climatic factors.

Exposure refers to the physical presence of people, livelihoods, species, or environmental, economic, social, or cultural resources in places that are put in harm (IPCC 2014). Exposure is directly related to the character, magnitude, frequency, duration, and areal extent of climate risks and physical hazards (Adger 2006; Burton et al. 1993).

Sensitivity indicates the degree to which a system is affected directly or indirectly, adversely or beneficially, by climate variability or change (IPCC 2007). This is the degree to which a system can absorb impacts without suffering long-term harm (Smith et al. 2003). Sensitivity is the predisposing condition or inherent attributes of a system, part of the socio, economic, political, or cultural dimensions, which incline people to risk or enable them to cope with stress (Cutter et al. 2009; Shepard et al. 2012).

Adaptive capacity is another internal attribute of the system that exists before the occurrence of disturbance. It represents the system’s ability to adjust to a disturbance to moderate potential damages, exploit opportunities, or to cope with the consequences (Gallopín 2006; IPCC 2014). It can be interchangeable between adaptive capacity with coping capacity or

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**Fig. 1** Conceptual framework of climate change adaptation planning. Source: Adapted from Bierbaum et al. (2013); Füssel and Klein (2006); IPCC (2007, 2012)
capacity of response. “Coping ability” tends to be applied for the short-term capacity to be survival while “adaptive capacity” or “capacity of response” implies longer-term or more sustainable adjustment (Gallopín 2006; Smit and Wandel 2006).

This study scrutinizes the type of risks and hazards in coastal cities (external perturbation) and how they impact the city and its residents as the proxy of exposure, the drivers and issues of socio-economic vulnerability as the proxy of sensitivity, the adaptive capacity, and the typologies of adaptation initiatives formulated to respond to these risks and vulnerabilities. Tables 1, 2, and 3 present the frameworks for risk and vulnerability identification.

The sub-group of sensitivity consists of the information on human-related drivers and socio-economic conditions and issues that add to the overall vulnerability of the cities. The framework of drivers and issues are projected to fall into six main aspects of an urban system, including the physical, social, economic, institutional, environmental, and cultural dimensions (Cutter et al. 2009; Mukherjee 1991; Revie et al. 2014; Wong et al. 2014). (Table 2).

The framework of adaptive capacity determinants is built mainly based on the work of Smit and Pilifosova (2001), Yohe and Tol (2002), and other scholars. Adaptive capacity is represented by ten determinants, classified into three levels, including the institutional, collective or community, and autonomous or individual adaptive capacity (Table 3).

Table 1 Type of coastal hazards and urban climate change risks

| Type of risks and hazards | Description |
|---------------------------|-------------|
| Coastal hazards Sea-level rise | A significant climate change threat as a result of increasing temperature leading to thermal expansion together with the glacier ice meltwater and the concentration of population in coastal cities and low-lying areas |
| Coastal flooding | The primary risk is caused by storm surge, sea-level rise, and tidal rise. |
| Storm/typhoon/cyclone | Storms are one of the major hazards in coastal regions. Severe storms can generate a storm surge, flash flood, and erosion. |
| Coastal/riverbank erosion | A secondary threat is caused by storm surge, extreme sea level, or intensive river water flow. It refers to the wearing or washing away of coastal lands or riverbanks. |
| Saltwater intrusion | A secondary threat is caused by sea-level rise and worsened by droughts affecting aquifer recharge when saltwater intrudes into surface and groundwater. |
| Tsunamis | A tsunami is a chain of water waves generated by the displacement of the large volume of water caused by undersea earthquakes, landslides, volcanic activity, or subduction of tectonic plates. |
| Urban climate-related hazards Urban heat island | More frequent hot days and warm spells will exacerbate urban heat island effects. |
| Drought | Increasing global temperature causes drought in many regions. |
| Inland flooding | Heavy rainfall and storm surges can cause inland flooding which can be exacerbated by poor drainage systems. |
| Other hazards Earthquakes | Coastal construction in seismic hazard areas will be potentially affected by earthquakes through ground shaking, liquefaction, surface fault ruptures, and other ground failures. |
| Land subsidence | In coastal areas, subsidence occurs due to the withdrawal of groundwater on a large scale, organic soil drainage, and sediment compaction. Land subsidence will increase coastal flooding. |
| Landslide | Some events such as erosion at a steep slope, earthquakes, floods, or heavy rains can trigger landslides, which can be worsened by human activities such as vegetation destruction and poor construction practices. |

Source: FEMA (2011); Finkl (2012); Revie et al. (2014); Wong et al. (2014)
capacity is the capacity of organizational systems, which consists of institution, governance, equity in risk management, and resource. Collective adaptive capacity, represented by technology, infrastructure, information management, and social capital, refers to the actions taken by groups, such as community initiatives that require collective resources and coordination. Autonomous adaptive capacity consists of human capital and public perception, which represent the individual and household capacity.

2.1 Typology of adaptation options and strategies

The three cornerstones of adaptation are identified as alter or minimize the exposure, reduce the sensitivity, and increase the adaptive capacity (Adger et al. 2005; Saroar and Routray 2013). They correspond to three general categories as classified in the IPCC Fifth Assessment Report (FAR): structural/physical, social, and institutional adaptation options (Noble et al. 2014). Other specific options and technologies for coastal adaptation include “protection,” “retreat,” and “accommodation,” which were first suggested by the IPCC Coastal Zone Management Subgroup (CZMS) in 1990 but are still widely used (Klein et al. 2001; Zhu et al. 2010). Since adaptation options vary across cities and the list of adaptation actions is diverse, this study uses an overarching classification according to the IPCC 2014 report (Table 4).

Inherited from the works of Dupuis and Biesbroek (2013), this study distinguishes between four types of adaptation policy to explore the intentionality to which climate change is considered in proposed adaptation measures and the substantiality to which the measures will contribute to reduce the vulnerability or enhance the resilience of the city or its residents (Fig. 2). Contiguous policies refer to measures that were designed to deal with other objectives rather than climate change impact and are limited to reducing climate change vulnerability but can contribute to enabling the necessary conditions for adaptation. Contributive policies, similarly, were not designed to tackle climate change but contribute substantively in moderating future vulnerability, such as measures for disaster risk reduction. Concrete policies are initiatives planned with the main focus to manage additional impacts of climate change and will contribute substantially in reducing vulnerability or enhancing the resilience of the system, for instance, the establishment of new organizations, policies, or structural interventions with climate change adaptation in mind. Symbolic policies, similarly, are initiated to respond to

| Dimension       | Description                                                                                                                                                                                                 |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Physical        | The sensitivity of land use, water supply, wastewater, and sanitation system, energy supply, transportation, telecommunication, public, and social facilities (Revi et al. 2014) |
| Social          | The sensitivity of demographic pattern, the pattern of human settlement, food security, and health and social services (Revi et al. 2014; Wong et al. 2014)                                                |
| Economic        | The sensitivity of individual economic statuses such as poverty, resource dependency, livelihood security or income diversification (Adger 1999), and economic sectors, including industry, fisheries, aquaculture, agriculture, and coastal tourism and recreation (Wong et al. 2014) |
| Institutional   | Sensitivity related to institutional aspects, such as land tenure, entitlement to resources, governance, or legislation (Adger 1999)                                                                              |
| Environmental   | The sensitivity of the natural system and ecosystem services (Revi et al. 2014; Wong et al. 2014)                                                                                                               |
| Cultural        | The sensitivity in cultural and spiritual aspects, such as social, cultural values, and heritage sites. (Revi et al. 2014)                                                                                       |
climate change but do not contribute directly to reduce the impact, for example, adaptation research or climate change vulnerability assessment (Dupuis and Biesbroek 2013). The two types of contiguous policies and symbolic policies are classified as groundwork initiatives, which are measures that enable adaptation to take place but do not reduce vulnerability directly, such as capacity building, gathering information, or reducing the social drivers of vulnerability. Meanwhile, contributive policies and concrete policies are classified as adaptation actions that directly aim for vulnerability reduction or resilience building to climate change (Araos et al. 2016; Lesnikowski et al. 2015).

### Table 3 Determinants of adaptive capacity

| Determinants                      | Description                                                                 |
|-----------------------------------|-----------------------------------------------------------------------------|
| **Institutional adaptive capacity** |                                                                             |
| Institutions                      | Institution is a crucial determinant of adaptive capacity that refers to institutional requirement and the decision-making frameworks for adaptation evaluation (Smit and Pilifosova 2001; Yohe and Tol 2002). This study will distinguish between institutions and governance based on some emerging studies (Engle 2011; Lebel et al. 2006) and the Oxford dictionary. Institutions refer to the structure of institutions and established law, practices, or custom which are accepted and used by many people. |
| Governance                        | Governance indicates the processes by which societies share power, including the participation in the decision-making process and the employed decision criteria. Both together refer to the structure of power, rights, and entitlements across multiple levels of government and its relationship with other stakeholders (Berman et al. 2012; Lebel et al. 2006). |
| Equity                            | Equity represents the allocation of power and resource accessibility (Smit and Pilifosova 2001). Equity or social justice is a significant focus of good governance (Lebel et al. 2006) and should be accounted in risk spreading processes through mechanisms such as insurance or government compensation (Yohe and Tol 2002). |
| Resource                          | The availability, distribution, and management of the resource. It refers to the ability to mobilize resources to anticipate or respond to shocks and stresses (Engle 2011; Smit and Pilifosova 2001; Yohe and Tol 2002). |
| **Collective adaptive capacity**   |                                                                             |
| Technology                        | The availability and access to technology at various levels and in all sectors will result in the range of possible technological options for adaptation (Smit and Pilifosova 2001; Yohe and Tol 2002). |
| Infrastructure                    | Adaptive capacity is likely to vary depending on the effectiveness of infrastructure (Smit and Pilifosova 2001) and refers to the ability of infrastructure to withstand extreme events and the ability to operate infrastructure under changing climate conditions such as ensuring water and energy supply (European Commission 2013). |
| Information                       | Refer to information needs and decision-making credibility through the ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers, themselves (Smit and Pilifosova 2001; Yohe and Tol 2002). |
| Social capital                    | Social capital presents in types of interpersonal relationship, and trust and reciprocity (Pelling and High 2005), where people or communities share norms and involve in networks that enable cooperation, such as sharing of knowledge, financial risk, and information in the time of crisis (Adger et al. 2003). |
| **Autonomous adaptive capacity**  |                                                                             |
| Human capital                     | The stock of human capital including education, training and skills, and personal security, including sufficient access to the decision-making process (Smit and Pilifosova 2001; Yohe and Tol 2002). |
| Public perception                 | Refers to the perception or awareness of the public to the source of stress and the significance of its exposure (Yohe and Tol 2002). Motivation and perception are important determinants of human actions, among which CCA is one example under uncertainty conditions (Grothmann and Patt 2005). |
In addition, to further explore the progress of adaptation planning, this study also notes the status of each adaptation initiative, including recommended, planned, ongoing status, and proposed project or implemented project. *Recommended initiatives* are measures suggested in the planning document without any assignment of time and actors of responsibility. *Planned initiatives* are the ones proposed in the document with the identification of time frame and involving actors. *Ongoing measures* are actions that have been implemented or partly completed and continue to function. *Implemented projects* are programs that have been implemented, and *proposed projects* are still in the phase of a proposal but have a detailed design of necessary actions, time frame, involving actors, and funding sources.

![Typology of adaptation options and policies](image)

**Table 4** Typology of adaptation options and policies

| Structural or physical options | Social targeted options | Institutional options |
|-------------------------------|-------------------------|-----------------------|
| • Engineered and built environment | • Education | • Economic |
| • Technology | • Information | • Laws and regulations |
| • Ecosystem-based measures | • Behavior | • Government policies and programs |
| • Services |

Source: Adapted from Chapter 14. Adaptation Needs and Option, IPCC Fifth Assessment Report (Noble et al. 2014)

![Typology of adaptation policies](image)

**Fig. 2** Typology of adaptation policies. Reprinted from Dupuis and Biesbroek (2013)
3 Methodology

Selection of case studies This study will focus on the study region of coastal cities in developing countries. According to the Global Climate Risk Index, the ten most affected countries in the period 1996 to 2015, regarding fatalities and economic losses caused by past extreme weather events, are developing countries (Kreft et al. 2016). Among them, all but one are low-income or low-middle-income countries.

Cities in developing countries located along or near the coast (within 100 km) that have completed either a vulnerability assessment, adaptation planning, or city resilience strategy are selected for this study. Since not all coastal cities have those required documents, this study uses a convenience sampling technique, a subjectively chosen sampling but can enable the investigation of many of the best practices of local adaptation planning efforts. Firstly, I compiled the list of cities from multiple sources, including the city members of the Local Governments for Sustainability (ICLEI), Cities and Climate Change Initiative (CCCI) (launched by the UN-Habitat), the Asian Cities Climate Change Resilience Networks (ACCCRN), and the 100-Resilient Cities network. Coastal cities in developing countries of four regions, including Asia, Africa, Latin America, and the Caribbean, and Oceania were selected. This step generated a list of 167 coastal cities in developing countries. The next step was to retrieve the documents on a city-by-city basis. First, I searched for adaptation planning documents on the city’s municipal website and the sponsor program’s website. If no adaptation document was found, I entered the name of a city together with the keywords of either “vulnerability assessment,” or “adaptation/action plan,” or “resilience strategy” in Google search to find the documents. The study targets documents in English but not limited to documents in other languages (specifically Portuguese, Spanish, French, Vietnamese and Indonesian) that can be translated into English with the assistance of Google Translate and cross-checked with a native speaker when necessary. Additional cities were added to the list with the reference from the retrieved documents because some programs fund multiple cities. Data were collected from September to December 2017 and updated in May 2018. The final dataset contains 45 coastal cities and towns: nine cities in Africa, 24 in Asia, seven in South America and the Caribbean and five in Oceania. (Fig. 3).

Data sources and analysis methods The study uses web-based climate change planning documents from cities as the source for identifying and characterizing types of vulnerability and adaptation responses. The primary data sources consist of the climate change vulnerability assessment, adaptation plan, climate action plan with the chapter of adaptation, and the city resilience strategy with climate change as a primary driver. From the selected documents, data were collected into two groups, types of vulnerability and adaptation options, using an Excel table format based on the theoretical framework as described in section 2.

Data are collected into three sub-groups to identify types of risk and vulnerability, including (1) types of coastal hazard, climate risk, and their impacts for the measurement of exposure; (2) the drivers and issues of socio-economic vulnerability for the measurement of sensitivity; and (3) adaptive capacity. This is a data-driven process, in which the main themes are guided by the

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1 The ten most affected countries by natural hazards (1996–2015): Honduras, Myanmar, Haiti, Nicaragua, Philippines, Bangladesh, Pakistan, Vietnam, Guatemala, and Thailand. Source: Global Climate Risk Index 2017 https://germanwatch.org/de/download/16411.pdf (retrieved on 20th September 2018)
described framework and emerged during the coding process. Data are analyzed in two rounds, the coding and the ranking process.

Followed the theoretical framework of exposure, sensitivity, and adaptive capacity as described, the coding process identified 11 natural hazards that most affect to coastal cities, 20 issues and drivers of sensitivity that are grouped into 14 main issues, and 10 determinants of adaptive capacity (Table 5).

These indicators, subsequently, are ranked following a three-level ordinal scale. Regarding the impact of coastal hazards and climate risks, low impact stands for the hazard having caused or potentially causing a low impact to the city and its citizens, moderate if the hazard causes moderate impacts or damages, and high if causing significant impacts or damages. Due to the specific characteristics of each hazard, the threshold to classify is different accordingly (see detail in Appendix 2, Table 2.1.). Involving the issues and drivers of social sensitivity, there is low concern if the issue is mentioned as an issue but without detail, moderate if the issue is not a priority concern or causes a moderate impact, and high if the issues is a priority concern or causes a significant impact (see detail in Appendix 2, Table 2.2.). Similarly, the evaluation of adaptive capacity is also at low, moderate, and high adaptive capacity in each specific determinant following the framework as shown in Table 3 in Sect. 2 (see detail in Appendix 2, Table 2.3.).

The coding for adaptation initiatives is conducted to explore three main aspects. Firstly, it classifies the typologies of adaptation options and strategies following Noble et al. (2014) (see Table 4). Secondly, the study distinguishes adaptation initiatives into four types of adaptation policy then grouping them into adaptation actions or groundwork initiatives to examine the intentionality of adaptation initiatives in considering climate change and their substantiality in vulnerability reduction or resilience building and their level of action (see Fig. 2). Thirdly, the study examines the status of each adaptation measure to explore the progress of adaptation planning, including recommended, planned, ongoing initiative, and proposed or implemented project.

To ensure reliability and validity, the study conducted a pilot content analysis with six cities to explore the main themes and examine the ranking scale before applying the analysis to the full samples. This study additionally applied the principle of a test-retest method to determine
reliability (Mackey and Gass 2005). Data were coded and ranked independently in two different times with 3 months lapse and constantly compared between cities to improve the consistency and accuracy. Similarly, all the discrete adaptation options of each city were recorded in an excel table, then applied two rounds of coding at different times and constantly compared between cases. Additionally, a peer debriefing was applied, which included extensive discussion with impartial peers in coding, ranking, and making consensus when inconsistency appeared.

4 Results

4.1 Exposure to natural hazards and climate risks in coastal cities of developing countries

The analysis shows that flooding (including both coastal and inland flooding), sea-level rise, and storm, typhoon, or cyclone are the most common natural hazards in coastal cities of developing countries (Fig. 4, see detail in Appendix 3, Table 3.1). All the studied cities have experienced flooding. Among them, 66.44% faced significant flood events with up to hundreds of fatalities, huge damages of assets and economic loss, and displacement of thousands of people. Sea-level rise (SLR), the second greatest risk, was assessed to have a moderate to a significant impact in more than two-thirds of coastal cities. This result, however, might be
underestimated due to the lack of climate change projection and data monitoring of local SLR in many cities in developing countries. For instance, climate change scenarios are not available at either a local or national level in Sri Lanka (Mahanama et al. 2013), or lack of localized measurement of observed SLR in Cambodia due to a lack of advanced weather and marine monitoring station (Fee et al. 2012). As a result, some cities only mention SLR as their potential risk without a projection. Nonetheless, SLR will influence pervasively and substantially in many coastal cities. With 1-m SLR scenario, more than 50% of Can Tho City would be inundated, while the coastline in Accra is estimated to retreat by about 200 m, and 60% of beaches in Dakar could disappear. Standing as the third most affecting hazard, storm, typhoon, and cyclone have caused significant damages to many coastal cities. Of the studied cities, 80% have been attacked in the last decade by the increasing frequency and intensity of storm and typhoon. Among them, 22% have experienced devastating storm attacks, such as Cyclone Sidr in Khulna (Bangladesh), Typhoon Haiyan in Sorsogon (Philippines), or Cyclone Pam in Port Vila (Vanuatu).

As a result of increasing extreme rainfall events coupled with the impact of sea-level rise and storm surge, coastal cities are also affected significantly by coastal or riverbank erosion. The coastline in many cities is eroding with an unprecedented rate at 1 m to even 10 to 20 m annually. Without adaptation measures, this situation, together with an increasing sea-level rise, would lead to a dramatic displacement of coastal communities. The increasing frequency and intensity of these coastal hazards align with the reported variation of rainfall patterns in many coastal cities. Out of 45 cities, 18 (40%) report an increasing trend of average annual rainfall, while another 11 cities (24%) report an intensifying rainfall in the rainy season but a decreasing trend in dry season illustrated by either historical data or projection of climate change models. These facts demonstrate that the majority of coastal cities will likely be

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Fig. 4 The number of cities addresses hazard exposure in the planning documents. High: the hazard causes significant impacts or damages to the city. Moderate: the hazard causes moderate impacts or damages to the city. Low: the hazard is mentioned as a threat without detail or at a low impact.

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2 The city of Hoi An (Vietnam) reports the severe coastal erosion at 10–20 m of shoreline eroded every year. Source: UN-Habitat, 2014, *Hoi An, Vietnam: Climate Change Vulnerability Assessment.*
affected by more intensity and frequency of extreme rainfall, which will lead to more flooding events and their associated consequences.

With the increasing trend of global temperature, coastal urban dwellings suffer significant drought and heat waves. Out of 45 cities, 36 (80%) report a historical record or projection of increasing temperature. Drought is already a recurrent hazard in many places (62% of the studied cities). The global temperature trend also leads to an increasing threat of heat wave in 35% of studied coastal cities. Dwellings in those cities have experienced a prolonged dry season with more frequent extreme hot days while less frequent cold days. With the increase of sea-level rise and drought, many coastal cities have suffered from saltwater intrusion, especially in prolonged dry seasons, which caused significant impact to the quality of water supply, loss in agricultural production, and degradation of the aquatic ecosystem.

Other hazards, including tsunami, landslide, and land subsidence, do not pervasively affect multiple cities but caused an extreme impact in specific locations. Tsunami, with its difficult predictability and widespread influence, has caused massive devastation in some cities, such as the 2009 tsunami in Apia or December 2004 tsunami in the coast of Sri Lanka. Meanwhile, heavy rain and the unsafe settlement location have caused significant landslides to impact those who live in upper and hilly areas in many coastal cities. Another issue with some big cities, particularly Bangkok, Semarang, Ho Chi Minh City, and Jakarta, is the land subsidence with an increasing rate due to excessive groundwater extraction exacerbated by increasing sea-level rise.

Given the complex impacts of multiple hazards coupled with the limitation in climate change information and climate monitoring, how do coastal cities in developing countries adapt to climate change presents a challenge. Adaptation planning will need a comprehensive assessment of climate change and natural hazard impacts and a flexible approach to overcome the data limitation.

4.2 Issues and drivers of social sensitivity

Regarding the sensitivity of the urban system, this study analyzes six fundamental aspects of an urban system, including the social, economic, institutional, physical, environmental, and cultural and other social issues.

**Socio-economic sensitivity** The analysis illustrates that rapid urbanization and urban migration are among the main drivers of urban sensitivity. Nearly two-thirds of 45 studied cities reported that rapid urban expansion had placed pressure on land, housing, infrastructure, essential services, and the environment (such as in Accra, Dakar, Dar Es Salaam, Kupang, Santos, Ho Chi Minh City, and Bangkok). This phenomenon, coupled with the lack of urban planning and limited coverage of basic services, has aggravated vulnerability of urban inhabitants, especially notable in the settlement in hazard-prone areas, the outbreak of disease due to lack of sanitation services, or the disruption during hazard occurrence (in Batticaloa, Honiara, Da Nang, Esmeraldas, and Port Moresby).

Insecurity of livelihoods and economic status is another significant issue in coastal cities of developing countries, where 75% of the studied cities experienced at least one of these economic issues, including a high rate of unemployment or informal employment, high level of poverty, food insecurity, and lack of housing or poor housing conditions. More than 40% of the studied cities have high to a very high rate of unemployment, or a large proportion of their population is in the informal economic sectors. The insecure employment has placed a large
population in those cities in a very fragile situation during the time of incidents. It also intertwines with other socio-economic problems, particularly poverty, food insecurity, and poor housing conditions. Nearly 50% of the studied cities reported that the high rate of poverty had hindered their capacity to adapt to climate change and current natural hazards. Lack of affordable housing and poor housing conditions is another impediment in those cities, with 44% of the cities encountering this problem. (Fig. 5, see detail in Appendix 3, Table 3.2).

**Physical sensitivity** The analysis demonstrates that inadequate or limited access to water and sanitation services is the main problem of coastal cities in developing countries. More than 90% of the studied cities suffer at least one of these issues, including water supply, limited coverage of the sewage system, inadequate drainage capacity, and poor sanitation or waste management. Water scarcity, quality, and limited availability appear to be the most concern in coastal cities of developing countries due to the increasing drought and sea-level rise exacerbating the problem of salinity. Poor sanitation and waste management have leveraged the vulnerability in these cities, such as minimal access to hygienic toilet facilities, and even people in some cities still need to share community toilets (Maputo and Greater Port Vila). Additionally, lack of mobilization and poor road conditions appear to be the second highest physical sensitivity in the studied cities. Nearly 70% of the cities reported these problems on their current transportation issues as well as its capacity to withstand shocks. Lack of connectivity, traffic congestion, poor road conditions, and inadequate public transport service are some main current problems of the transportation system in those coastal cities. Cities reported sensitivity of transportation system as a barrier to adaptation since accessibility is compromised during disasters due to the solitary mass transit route, main routes located near the coast or riverbanks where they are prone to cyclones and flooding, and the improper design

![Diagram of physical sensitivity](image)

**Fig. 5** The number of cities addresses social vulnerability in the planning documents. High: mention as a priority issue or with a significant impact. Moderate: mention as an issue with a moderate impact or not a priority concern. Low: mention as an issue but without detail
of transport system to endure shocks (Apia, Dar Es Salaam, Hoi An, Lami Town, Manado, Port Moresby, Greater Port Vila, and Sorsogon).

**Institutional, environmental, cultural, and other social sensitivity** Some other issues, particularly land tenure, entitlement to resources, and environmental degradation, are among the main concerns. Of the studied cities, 33% report on the issues of land tenure, particularly illegal land occupation and no formal tenure security. To some extent, these problems have prevented people from reinforcing their houses, resulting in increased vulnerability, low quality of life, and low adaptive capacity. In another aspect, two-thirds of the studied cities concern on the ecosystem deterioration and their environmental degradation as a result of improper human activities, recurrent disasters, and changing climate. These problems shed a positive light on the importance of the ecosystem in coping with recurrent hazards and adapting to climate change, in which ecosystem-based measures should be a considerable adaptation option.

### 4.3 Adaptive capacity of coastal cities in developing countries

The analysis illustrates ten indicators of adaptive capacity as shown in Fig. 6 (see detail in Appendix 3, Table 3.3). These indicators are classified into three levels, including the institutional, collective or community, and autonomous or individual adaptive capacity.

**Institutional adaptive capacity** is the capacity of organizational systems, which consists of urban governance, institution, equity in risk management, and economic resource. Urban governance and institution appear to be the primary determinants of this category with 67% and 78% respectively of the studied cities assessed these indicators. The majority of the cities have ample policies and appropriate institutional framework to support climate change response activities but still face numerous limitations in governance. The most reported significant limitations are the lack of regulatory enforcement, political resistance in

![Fig. 6](image_url)  
*Fig. 6* The number of cities addresses adaptive capacity in the planning documents. Scale: 3: high; 2: moderate; 1: low adaptive capacity
implementation and enforcement, lack of resource-sharing mechanism among institutions, and inadequate financial resources (Byblos, Kalmunai, Esmeraldas, Kupang, Accra, Mullaitivu, Sorsogon). Cities reported the financial impediment, particularly limited budget allocation for climate-related activities, resulted in the limitation on preparatory and preventive actions, including the relocation of hazard-prone communities and the heavy dependency on international recovery funds (Bandar Lampung, Esmeraldas, Honiara, Hue, Mannar, Castries). As a result, access to finance is an issue of adaptation, especially to poor households and communities in high-risk areas (Hue, Honiara, Greater Port Vila). While equity is a crucial factor of good governance (Lebel et al. 2006), few cities (only 6 out of 45 cities) mention this determinant in their adaptation planning report. This indicates that there is still a lack of equity consideration to vulnerable and marginalized groups in climate change and risk management framework.

Regarding collective adaptive capacity, corresponding to the sensitivity caused by inadequate infrastructure, 60% of the cities (27 out of 45 cities) assessed their capacity of infrastructure. Among them, 22.2% of cities have a high level of capacity, while 40.7% moderate and 37% low capacity of infrastructure. Lack of disaster-resilient infrastructure, lack of mobilization, and limited coverage of essential services are reported as prominent barriers of city adaptation (Sihanoukville, Port Moresby, Mullaitivu, and Kalmunai). In terms of information management, 24 out of 45 cities assessed this determinant with 25% (6 out of 24) has a high capacity, while 41.67% and 33.33% are in average and low capacity. Some cities are pioneers in setting up an early warning system and providing a wealth of information to their citizens while others still lag behind. Lag-behind cities lack in information and knowledge in climate change, have limited risk database and risk management tools such as the early warning system, and have inadequate weather monitoring and warning communication to communities (such as Bandar Lampung, Batticaloa, Esmeraldas, Mannar, Sihanoukville, and Castries).

This analysis also found that enhancing social capital is a strength in many cities in developing countries. There are some implemented programs for community empowerment and resilience building at the grassroots level, and social cohesiveness enhancement to adapt to climate change. Some examples include the grant scheme for community risk adaptation measures in Apia, the tradition of close-knit family connections and social obligations (Apia and Port Moresby), the Hi-5 public health initiative to teach skill in improving health (Makassar), the citizen’s riverfront initiative (Manado), assembled disaster preparedness groups and communities’ rescue teams based on social cohesiveness due to past experiences to natural hazards (Iloilo, Semarang, and Hoi An), and the provision of mutual support during disasters led by community leadership (Honiara and Greater Port Vila). Building social capital and incorporating local knowledge, therefore, would be a potential area of adaptation in cities in developing countries.

Regarding autonomous adaptive capacity, out of 45 studied cases, 16 cities assessed their human capital while 19 cities assessed public perception. All reported cities are suffering significant stress due to the high rate of unemployment, lack of qualified human resources, lack of proper training activities, and monochrome livelihood opportunities. Meanwhile, 47% of reported cities in public perception claimed a low level of awareness on climate change or lack of risk responsiveness. Low levels of public perception and human capital will hinder individual responses to climate change since awareness and education level are good predictors of behavioral adjustment to climate change (Semenza et al. 2008).
4.4 Adaptation options and strategies

4.4.1 Typologies of proposed adaptation measures

From the adaptation planning documents in 45 cities, this research retrieved and analyzed 1565 adaptation initiatives. Structural and social measures appear to be equally crucial for adaptation when accounting for 37.70% and 34.5% of the adaptation measures, respectively, while institutional measures capture lesser focus with 27.8% of total initiatives. Engineered and built environment measures, informational, institutional policies and programs, and education initiatives are the most essential typologies of adaptation when accounting for the highest percentage of adaptation measures (Fig. 7). Effective adaptation will need a combination between protection and accommodation by engineering and built environment measures, social capacity building by improving information management and educational opportunities, and long-term and integrated institutional policies and programs. Figure 7 also illustrates that the ecosystem-based adaptation, technological, laws and regulations, and economic options are essential. Ecosystem-based measures are increasingly utilized with an average of three initiatives per city and a variety of non-structural initiatives using green infrastructure to cope with increasing temperature, drought, urban flooding, storm and typhoon, sea-level rise, coastal or riverbank erosion, and biodiversity management. (more detail in Appendix 4).

4.4.2 Level of action and type of adaptation policy

Table 6 illustrates more proposed adaptation actions than the groundwork initiatives. Cities put more efforts and resources into interventions that will directly reduce the vulnerability or enhance their resilience. Proposed interventions, however, are mainly contributive policies with 52% of the total planned measures while a relatively modest proportion are concrete policies (18%). Symbolic policies that consider climate change impacts take a tiny portion at

![Figure 7. Typologies and policy types of proposed adaptation options and strategies](image-url)
9%. Planned adaptation measures still mainly concentrate on existing issues and current hazard impacts rather than taking into account projected climate change. This reflects the truth that climate change remains an uncertainty, and not all cities, especially in developing countries, have conducted downscaling models of climate change scenarios. Thus, they hinder the cities’ capacity to identify more concrete interventions that may be necessary to adapt to climate change. Instead, many cities choose to implement the no-regret measures, which will yield an essential result in reducing vulnerability regardless of the uncertainty of climate change impacts.

4.4.3 Status of adaptation measures

Noting the status of proposed adaptation initiatives, the highest number of measures are in the stage of recommendation (44%), a moderate portion in planned stage (38%), a smaller portion of measures are ongoing (16%), and the least are proposed or implemented projects (Table 5). Adaptation actions are still in the beginning stage in coastal cities of developing countries with a modest number of ongoing actions and implemented projects as reported. Many cities are in an early stage of adaptation planning with a high number of proposed actions as the recommendation without any specification of involved actors and the timeframe of implementation. Meanwhile, other cities are already making good progress in adaptation planning and can be a source of experience transfer in city networks.

5 Discussion

Two key questions of adaptation framing, “Adaptation to what?” and “How does adaptation occur?” (Funfgeld and McEvoy 2011), have been addressed in this study through the elaboration of types of vulnerabilities and proposed adaptation measures with selected case studies in coastal cities of developing countries. This study extends the current literature on the risks and vulnerabilities of coastal cities globally and cities in developing countries to climate change by illustrating how complicated those risks and vulnerabilities in the coupled-sensitive context of coastal cities in developing countries as well as the range of adaptation responses are.
The study identified 11 natural hazards, 14 socio-economic-environmental issues, and 10 determinants of adaptive capacity that are most significant in coastal cities in developing countries. City-level vulnerabilities in developing countries are caused by multiple layers, not only the hazard exposure but also their current socio-economic conditions, insufficiency of the physical system, and limited adaptive capacity. Separately, these findings are not new in coastal exposure to climate change and sea-level rise (Wong et al. 2014, Boateng 2012, Dasgupta et al. 2009, Alam and Collins 2010, Bathia and Das 2016), urban vulnerability to increasing global temperature (Revi et al. 2014), and acute socio-economic issues of developing countries, such as poverty, sensitivity of informal employment, water, and sanitation services (Fields 2011; WHO and UNICEF 2017). These issues, when interacting, create an intensely vulnerable status in coastal cities in developing countries due to the complexity and multi-layers of risks and vulnerabilities, which will need extensive attention and a comprehensive approach in adaptation planning. Importantly, this sensitive status does not happen in some extreme cases but across multiple coastal cities in developing countries.

These findings call for adaptation to climate change being not only responding to future climate risks but also current hazards, existing socio-economic sensitivity, and capacity deficiencies. CCA policies cannot separate from social-economic development and capacity building. A coordination mechanism for inter-policy is, therefore, necessary to manage the trade-offs between multiple priorities, including climate change resilience, socio-economic development, and capacity building. Suggested directions for a coordination mechanism include, but are not limited to, mainstreaming CCA into existing development priorities and the establishment of a coordination office. Mainstreaming CCA into existing management activities and development plans will require adequate consideration of short-term solutions incorporated with a long-term planning horizon (Florano 2015; Huq et al. 2003). Meanwhile, the establishment of a coordination office or mechanism is necessary to manage climate change-related issues and to enable the collaboration between agencies to tackle climate change. For instance, the newly established Climate Change Trust has enabled the coordination of multilevel of actors and institutions to sustain climate initiatives in Surat city, India (Karanth and Archer 2014).

Given these recognized types of vulnerability, how coastal cities of developing countries plan to respond to these issues and adapt to climate change is a crucial question. The second part of this study illustrates that coastal cities share relatively similar efforts and resources for structural/physical initiatives and social initiatives but less with institutional aspects. Prominent types of adaptation measures include engineered and built environment; informational, educational initiatives; and institutional policies and programs. While those measures are crucial to tackling short-term and long-term adaptation, extensive reliance on engineered measures can be problematic due to their expensive cost, potential failure, and shortsighted vision (Gibbs 2016; Klein et al. 2001; Tobin 1995). Structural measures, however, in many cases, are seen as a cost-benefit solution, such as in high-urbanized areas where the cost for relocation is too expensive (Gibbs 2013). The selection of adaptation measures, therefore, will depend on specific context, but considering climate change impacts is crucial to improve adaptive capacity for future needs.

The analysis also found that there are more proposed adaptation actions than groundwork initiatives (70% versus 30%), but the majority of these proposed initiatives are contributive and contiguous policies rather than concrete and symbolic policies (73 vs. 27%). Coastal cities in developing countries are putting more resources into reducing their current vulnerabilities rather than to future climate change risks. They are currently overwhelmed by their existing
issues, such as recurrent hazards, socio-economic deficiencies, and climate change remains a poorly understood uncertainty. Increasing climate change awareness, expanding knowledge, and an analytic framework to incorporate climate change issues into current development agenda are crucial for cities to manage the trade-offs between short- and long-term objectives.

The finding of more adaptation actions in place is consistent with the work of Araos et al. (2016) at city level but contrary to the findings of Lesnikowski et al. (2013) on national-level responses. This reflects higher adaptation actions happening at the local level while more groundwork initiatives are found at the national level. These findings are reasonable since cities and their citizens are the first responders of disaster risks as well as climate change impacts. The findings, however, raise a crucial question in climate finance, which needs to be further explored, that if the local level receives adequate funding and resources to tackle climate change.

6 Limitation

This study tolerates from the limitation of desktop analysis and the method of case study selection. Relying on a desktop analysis, the study might be impacted by the subjective lens of the planners who conducted the planning documents and cannot capture actual adaptation implementation. The study acknowledges this limitation and addresses it by data triangulation with multiple sources of secondary data, including planning documents, related peer-reviewed articles, and reports of cities in climate change impacts and adaptation. The selection of case studies might reflect bias because of this study’s sampling method and the inability to capture adaptation planning documents that have not been published online or were published in languages that could not be effectively translated into English. Nonetheless, as an in-depth overview covering several coastal cities across diverse social, cultural, and physical environments, this study still provides insight into the range of climate risks faced by coastal cities in low-to-middle-income countries and the breadth of strategies deployed in response.

7 Conclusion

Some important implications for adaptation planning emerge from this study. Climate change vulnerability in coastal cities in developing countries is complex and driven by multiple factors. The study, therefore, calls for a comprehensive approach in adaptation planning to tackle future climate risks, current hazards, existing socio-economic sensitivity, and capacity deficiencies. CCA policies will be not effective without considering social-economic development and capacity building. The second part of this study seems to respond to this call as cities proposed an adequate combination of structural, social, and institutional measures to adapt to climate change. Without evidence of the results, it is not possible to judge the effectiveness of the adaptations. These findings imply that a combination of a wide range of adaptation options is a current trend and can be seen as a win-win solution under the uncertainty of climate change and the constrained capacity of many cities in developing countries. Addressing existing problems is a feasible solution to enable adaptation to future climate change impacts. This trend, however, might suffer from shortsighted interventions rather than future adaptation. Therefore, a coordination mechanism, such as mandate policy on mainstreaming climate change adaptation, a climate change coordination office, or
incorporating climate change scenarios, is essential for cities to address the climate change issues among other development priorities.

Adaptation planning is still at the beginning stage in many coastal cities of developing countries where a majority of proposed initiatives are recommendations. Getting those cities into existing or new city network for experience and knowledge exchange is essential. Those cities could benefit from adaptation planning guidelines and learning from the experience of other cities to reinforce their planning document to facilitate on-the-ground actions. Potential future studies could include the framework for adaptation planning, an association of vulnerability and adaptation responses, or the best practices of adaptation planning in the context of developing countries.

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